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C. EDGAR ALLEN, A.M.I.E.E., Etc.

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Scientific Boiler Control.

SCIENCE has in later years forced its way gradually into many of those fields of engineering practice which we had been formerly content to regard as purely and entirely practical, and it cannot be denied that the movement in favour of scientific guidance and assistance in the execution of practical tasks has resulted in increased economy and efficiency in many ways.

This general desire to abolish as much as possible rule-of-thumb methods, and to turn to good account the many and valuable fruits of more recent scientific research is unquestionably responsible to a considerable extent for the amount of attention which is just at present being bestowed upon steam boilers and their furnaces.

But few who have studied the subject will dissent from the statement that steam boilers really needed this attention more than any other portion of a power plant.

Although boilers and furnaces themselves have been very much improved of late, there is still scope for improvement in the methods adopted to convert the fuel into steam.

For years past the great bulk of steam users, with few notable exceptions, has been content to leave the problem of stoking almost entirely in the hands of the fireman, who was supposed to be fully capable of dealing with so complex a material as coal undoubtedly is, entirely by virtue of his experience, which consists principally of following more or less faithfully in the footsteps of those before him, who, if it were possible, knew even less about what actually takes place within a boiler furnace, than himself.

Nobody would ever seriously suggest that a good stoker should be able to tell his steam pressure without the use of a pressure gauge, and yet the idea is pretty general that this same stoker should be able to judge whether he is using the correct draught pressure and the right thickness of fire; whether he is feeding coal at the proper rate; and whether he is obtaining the correct furnace and exit temperatures, simply by looking at his fire.

That experience without guidance cannot teach these things, and that the difference between good and bad stoking is anyhow sufficiently alarming to warrant careful investigation, is perhaps best shown by the following remarks offered by Mr. W. Francis Goodrich, in a paper read last year before the Association of Engineers-in-Charge. He said:—

> "Many trials have clearly shown that there is a vast difference in the results obtained by firemen, even when burning similar fuel and meeting a similar demand for steam. Firing the same boiler in turn, burning a similar fuel, and evaporating the same weight of water, it has been shown that the most inefficient of five different men has burned 29 per cent more fuel than the best of the five firemen, there being such a marked difference in the results obtained between the best of the five and the four others, that the only possible course was to discharge the latter, who had demonstrated that they would waste or lose far more than they earned every week.

This is an experience which will no doubt be borne out by many who daily handle firemen, and could possibly relate similar or even more striking instances.

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Granting, therefore, that some scientific guide or indicator would be of real value to the man in charge, the point is to investigate in what direction this is most likely to be found, and found in a shape which will be really practical and also simple in its application.

As the burning of fuel in a furnace is purely a chemical process, it is not surprising that those in search of a remedy for existing conditions should have turned to chemistry for it, where it has indeed been found in a continuous and automatic analysis of the products of combustion.

There are now to be had so-called CO_2 recorders, instruments which produce practically automatically a certain number of records per hour of at least one of the products of combustion, and the most important one: carbon dioxide.

This is formed when carbon is brought into intimate contact with a sufficiency of oxygen, as is done by forcing air over the grate in a boiler furnace, in the presence of a sufficiently high temperature.

But the carbon in the coal is not always burned to CO_2; it may be changed only to CO or carbon monoxide. Or any particle of CO_2 may be retransformed into CO if it should, in its passage through the fire-bed and flues to the chimney come in contact with atoms of highly heated carbon. Now both CO_2 and CO are colourless gases, and the proportion in which they are present in the furnace gases can only be determined by chemical analysis.

A pound of dry carbon burned entirely to CO_2 gives heat equal to 14,600 B.T.U., whereas the same weight of the same carbon burned to CO only yields 4,450 B.T.U. It follows at once that if we discover a low percentage of CO_2 in our exit gases, we must be losing heat which should be transmitted to the water in the boiler, and inversely a high percentage of CO_2 should mean that we have secured the transmission of most of the heat generated by the combustion of the fuel to CO_2. Generally speaking, this has been proved to be true in practice.

Two factors must, however, be taken into consideration if the conclusions formed from an estimation of the CO_2 contents of the exit gases are not to mislead us slightly. These are the presence of CO, when the percentage of CO_2 is high, and the temperature of the gases at the stack.

Considering, as shown by above figures, that CO is a heat absorber, appropriating some 10,150 B.T.U. per pound of carbon from every particle of CO_2, which is reconverted into CO, it is obvious that it would be little use to produce a set of conditions which, whilst securing a high percentage of CO_2, also has a tendency to encourage the presence of CO in appreciable quantities.

Although it is not at the present moment practicable to construct continuous recording machines for the estimation of CO, —and occasional snap tests are of little value—this danger of CO may be readily guarded against.

As mentioned, CO is formed in the first place where sufficient oxygen is not available to complete the oxydising or burning process, and form CO_2. It follows that all we have to do to prevent this initial formation is to admit sufficient air to ensure an ample supply of oxygen. As the rate of combustion in average plants in our present-day furnaces already demands an excess of air, if steam is to be kept up, cases of too little air are comparatively scarce. Moreover, where the formation of CO is due to a shortage of air supply, the fact will be indicated by a low percentage of CO_2 shown by the CO_2 recorder.

There remains the question of a transformation of CO_2 back to CO in its passage to the stack. This possibility has been shown to be comparatively remote, so long as the percentage of CO_2, as shown by the recorder, is not more than 14 to 15 per cent. The formation of CO under these conditions is most probably due to a low velocity of the gases in the furnace at a high temperature, which encourages contact of particles of CO_2 with highly heated carbon. Such conditions are decidedly undesirable; they are, however, very rare in practice, as they are only possible where the duty on the boilers is very light. We may thus safely accept the guidance of the CO_2 record, provided that we do not strive to attain results averaging more than 14 to 15 per cent. of CO_2.

Before showing now what it really means in figures to have a low, or on the other hand, to have a high percentage of CO_2 showing on the chart of a CO_2 recorder, a few remarks may be added regarding the temperature of the stack gases.

Since economisers have become popular, at least with land installations, it is often erroneously considered an advantage to show a high temperature in the flues leading to the economiser. It is pointed out that this will mean a higher temperature for the water in the economiser, and the fact is quite overlooked that had the heat been utilised in the boiler itself, the total efficiency would have been much greater. This illustration is used to emphasise the importance of continuous records of the

temperature of the exit gases, which temperature should be kept at the lowest obtainable limit consistent with a good draught, for this reason.

A high temperature at the stack, which shows that a large proportion of the heat which should have been transmitted to the boiler is being wasted, is due either to conditions unfavourable to complete combustion of the fuel and the gases given off by it, immediately over the grate, or to too high a draught pressure, causing the gases to travel at so high a velocity as not to allow the boiler sufficient time to absorb all or most of the heat carried in them.

As far as the first cause is concerned, this would in all cases be clearly indicated on the CO_2 recorder by a bad record; but the latter possibility, though comparatively remote, renders it desirable to advise consideration of the temperature of the exit gases in addition to the analysis of their percentage of CO_2.

Consider now the losses actually occasioned in a boiler furnace in relation to the greater or less attention paid to the CO_2 contents, and the temperature of the exit gases.

The following are figures computed from actual experiments by Mr. O. L. Peard in one of the large London power plants:—

With 5 per cent. of CO_2 at 500° F. the loss is 35 per cent., at 400° F. loss is 28 per cent.
With 7 per cent. of CO_2 at 500° F. the loss is 25½ per cent., at 400° F. loss is 20 per cent.
With 10 per cent. of CO_2 at 500° F. the loss is 18 per cent., at 400° F. loss is 14½ per cent.
With 12 per cent. of CO_2 at 500° F. the loss is 15½ per cent., at 400° F. loss is 12½ per cent.
With 14 per cent. of CO_2 at 500° F. the loss is 13½ per cent., at 400° F. loss is 10½ per cent.

Briefly, this shows that if an engineer can, by the use of a CO_2 recorder, increase the percentage of CO_2 in the exit gases from 5 to 14 per cent., he will have effected a clear saving on his coal bill of 21½ per cent. If he can succeed in reducing his temperature at stack by a hundred degrees at the same time, the saving will amount to 24½ per cent.

Occasional tests cannot be expected to provide a reliable indication of the average conditions, as the firemen are well aware when they are taken, and there is no guarantee that the good results shown at the moment are maintained throughout day and night. Such a guarantee can only be furnished by a CO_2 continuous recorder.

Now it might be said that it is one thing to show up bad results, but quite another to remedy them, and it must, of course, be realised that a "tell-tale"—for that is what a CO_2 recorder really is—cannot automatically remedy the defects which it points out. However, it is not difficult to see that such a machine is, nevertheless, of great value, when one remembers that stoking consists after all of but a few in themselves very simple manipulations; and given the means to know what is going on, good results can be obtained in a very short time even by the stokers themselves. The success with which CO_2 recorders have met during the last few years in land installations—there are probably now some 800 of various types in use in Great Britain—is alone sufficient to prove this.

Let us now examine into the various manipulations which affect the CO contents of the exit gases. There is first of all the air supply. This is undoubtedly the most important factor.

It has already been said that we cannot in practice feed only the quantity of air which would furnish no more than the required volume of oxygen, we must have an excess, but this excess should be kept down as low as is possible, for every pound of excess cold air that we admit to a furnace not only lowers the temperature of that furnace, but in addition it must be heated to the temperature of the exit gases, which is an obvious waste.

In addition to the CO_2 recorder, which shows this excess, draught or pressure-gauges to guide the stoker will be found extremely valuable, especially where the conditions of load are comparatively constant, and are, of course, already in pretty general use.

The points next in importance are the thickness of the fire and the intervals between stoking (speaking of hand-fired furnaces).

Finally, there are such considerations as repairs to the settings, cleaning of the boiler shell, alterations to the grate, fire-bars or flues, stopping of excessive radiation and many others.

Each adds its little share to the general improvement, with the inevitable result that after a month or two the CO_2 record will show that efficiency and economy have been very considerably increased, and this without material structural alterations or additions, and without any considerable outlay.

In conclusion mention may be made of one design of recorder, known as the "Sarco," which was one of the first on the market, and one very generally used. It is understood to be the only one of which an adaptation for marine purposes* will be shortly available.—["Proceedings of the Institute of Marine Engineers."]

* A description of this will appear in a future issue.

Safety-Valves for Locomotive Boilers.

By C. HUGH SUMNER, Wh.Ex.A.M.Inst.C.E.

The following article is the outcome of a Report by a Committee to the American Railway Master Mechanics' Association on the size and capacity of safety valves for locomotive boilers. An abstract of this report was published on pages 299—300 of the present volume. (Ed. *E.R.*)

THE design of safety valves for locomotives does not appear to have received the attention which it deserves, considering the paramount importance of these fittings. In this article the author proposes to indicate briefly the principles underlying correct design, and to point out the defects inherent in spring-loaded valves. Reference will chiefly be made to the "Ramsbottom" valve, but the same reasoning may be applied to any type of safety valve used for locomotive boilers.

The three principal considerations to be borne in mind when designing a safety valve are:—

1. *Capacity.*—The valve must be capable of discharging the steam as fast as the boiler can generate it.
2. *Safety.*—The valve must be absolutely "fool-proof"; there must be no possibility of unauthorised persons putting extra load on the valve, once it has been tested and put in position.
3. *Reliability.*—The valve should be of simple construction, and not liable to stick or get out of order.

1. *Capacity.*—The area of opening of the valve, shown at *a a*, Fig. 1, depends on two factors, viz., the maximum rate of evaporation the boiler is capable of, and the velocity of the escaping steam. The weight of water evaporated in the boiler of an express engine may be anything up to 9 or 10 lbs. per sq. ft. of heating surface per hour. Assuming that the maximum rate per sq. ft. of heating surface per hour is 10 lbs., then

$$W = \frac{10 \times HS}{60 \times 60} = \frac{HS}{360}$$

where W = weight of steam generated per second

HS = total heating surface in sq. ft.

The velocity of the escaping steam can be approximated to as follows:—

According to Professor Perry ("The Steam Engine, 1900," p. 611) the velocity of steam flowing into the atmosphere is about 1,400 or 1,500 ft. per second. This value, no doubt, is for an orifice of square or circular shape, and without sudden contraction. But the opening in a safety valve is very different, consisting of a narrow annular space, as shown in Fig. 1. The difference between the two cases is better seen in Fig. 2, (*a*) showing a circular orifice, and (*b*) an annular orifice, whilst (*c*) illustrates a safety valve orifice; the shaded portion represents the opening in each case. The influence exerted on the flow of steam by the shape of the opening depends on what is known as the "hydraulic mean depth," *i.e.*,

$$\frac{\text{Area of opening in square inches}}{\text{Total perimeter of opening in inches touched by fluid.}}$$

Assuming the lift of a safety valve to be $\frac{1}{12}$ of the diameter, then the "hydraulic mean depth" for (*c*), Fig. 2, will be

$$\frac{\pi d \times \frac{d}{12}}{2\pi d} = \frac{d}{24}$$

whilst for (*a*) the $HMD = \frac{\frac{\pi d^2}{4}}{\pi d} = \frac{d}{4}$.

∴ the ratio of the HMD of the valve orifice to that of the circular orifice will

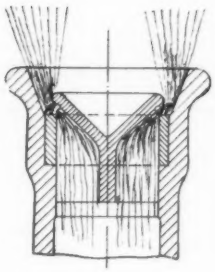

FIG. 1.

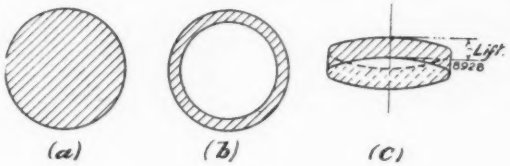

FIG. 2.

be as $\frac{d}{24}$ to $\frac{d}{4} = \frac{1}{6}$. Consequently the probable velocity of the steam will be $1{,}400 \times \frac{1}{6} = 233$, say 230 ft. per second.

The necessary area of opening can now be determined.

Let HS be the total heating surface in sq. ft.

„ W „ weight of steam generated in lbs. per second $= \frac{HS}{360}$

Let V be the volume of steam generated in cub. ft. per second

„ P „ absolute pressure in lbs. per sq. in.

„ A „ area of valve opening in sq. ins.

Then $A = \frac{144\,V}{230}$.

For pressures between 100 lbs. and 250 lbs. per sq. in. V may be taken equal to $\frac{460\,W}{P}$.

$$\therefore A = \frac{144 \times 460\,W}{230 \times P} = \frac{144 \times 460 \times HS}{230 \times 360 \times P} = \frac{0{\cdot}8\,HS}{P}.$$

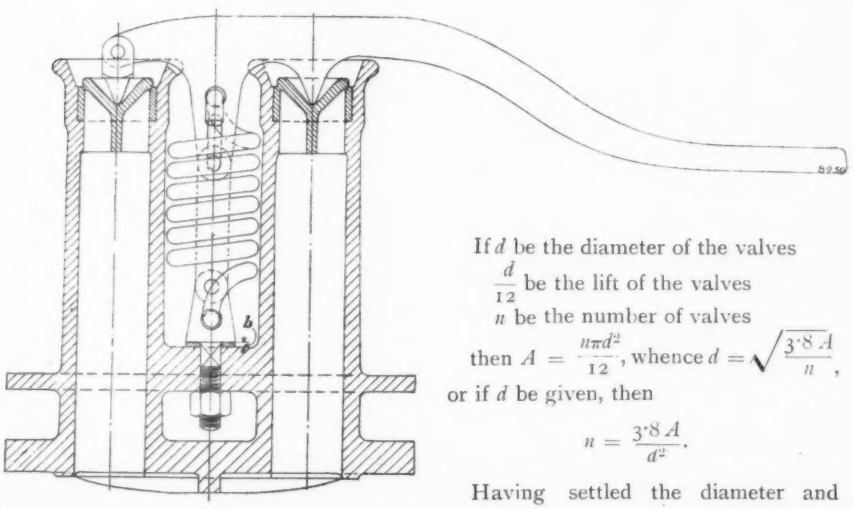

FIG. 3.

If d be the diameter of the valves

$\frac{d}{12}$ be the lift of the valves

n be the number of valves

then $A = \frac{n\pi d^2}{12}$, whence $d = \sqrt{\frac{3{\cdot}8\,A}{n}}$,

or if d be given, then

$$n = \frac{3{\cdot}8\,A}{d^2}.$$

Having settled the diameter and

number of the valves, the necessary dimensions of the springs can be determined. In the "Ramsbottom" safety valve one spring takes the load of two valves, but in other types of safety valve there is generally one spring to each valve. The load on the spring is given by the formula $T = n\frac{\pi}{4}d^2P_1$, where T is the tension on the spring, the other letters having the same meaning as before, P_1 being the gauge pressure, as the valve is subjected to atmospheric pressure. When round wire is used, the size of wire is given by the equation

$$S = \sqrt[3]{\frac{8TD}{\pi f}}.$$

S being the diameter of the wire in inches
D „ „ „ centres of coils in inches
f „ safe stress in lbs. per sq. in.

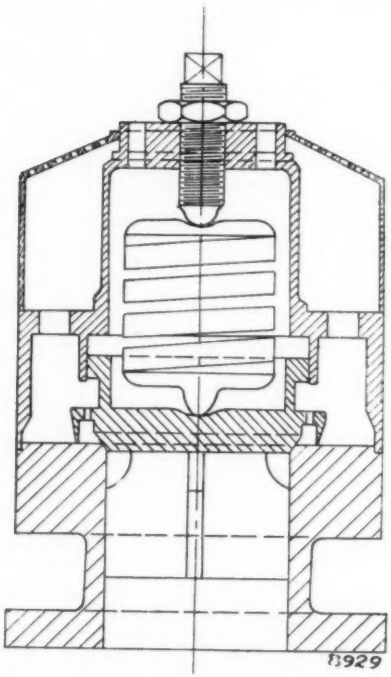

FIG. 4.

f may be taken at 40,000 to 50,000 lbs. per sq. in. Formulæ for other sections of wire are given in the pocket-books.

When deciding the diameter and number of the coils care should be taken to keep the deflection per unit load as large as possible, so that the valve will open promptly and wide without raising the pressure unduly. The deflection varies as TND^3 for any section of wire (N being the number of coils), consequently it is important to keep the diameter of the coils as large as can be conveniently arranged. The number of coils is generally limited by the amount of head-room available on the top of the boiler. Especially is this the case in the "Ramsbottom" valve (see Fig. 3), where the coils rarely exceed six in number.

The beneficial effect of increasing the diameter of the coils is illustrated by the following example.

The diameter of each of the two valves of a "Ramsbottom" safety valve is 3 in., pressure 160 lbs., spring six complete coils, diameter of coils $= 3\frac{1}{2}$ in., diameter of wire $= \frac{3}{4}$ in., maximum lift $= \frac{1}{4}$ in.

$$T = \frac{\pi}{2} \times 3^2 \times 160 = 2{,}262 \text{ lbs.}$$

The deflection $\Delta = \frac{0{\cdot}66\,TND^3}{10^6 \times S^4}$, N being the number of coils. Therefore the increase of load necessary to extend the spring $\frac{1}{4}$ in. $= t = \frac{{\cdot}25 \times 10^6 \times ({\cdot}75)^4}{0{\cdot}66 \times 6 \times (3{\cdot}5)^3}$ $= 466$ lbs., representing an increase of pressure of 33 lbs. per sq. in.

By making the coils 4 in. diameter instead of $3\frac{1}{2}$ in., t will become $\frac{466 \times (3{\cdot}5)^3}{4^3}$ $= 312$ lbs., the corresponding increase of pressure being 22 lbs. per sq. in. That is to say, that with $3\frac{1}{2}$-in. coils the pressure must rise from 160 to 193 lbs. before the valve is wide open, whereas with 4-in. coils the maximum lift is reached at 182 lbs. In ordinary working, however, the fireman takes steps to reduce the pressure when the boiler is blowing off hard, either by putting on the feed, or by closing the damper, so

that such high pressures are not the rule, but nevertheless, their possibility should be borne in mind when designing the springs.

To overcome this difficulty of the pressure rising as the valve opens, "Pop" valves have been introduced, which, by means of a lip on the edge of the valve, utilise the reaction of the escaping steam, thereby obtaining the increased force necessary to compress the spring. A valve of this type is shown in Fig. 4. These valves open well, but have the serious fault of not shutting until the steam has fallen well below the opening pressure. They are also apt to be noisy: a more serious objection with a locomotive than with a factory boiler.

2. The second condition is provided for by making the adjusting nuts screw up against a shoulder or ferrule. In the "Ramsbottom" valve, the space b, in Fig. 3, between the shoulder of the eye-bolt and the bridge, is fitted with a washer of the proper thickness after the spring has been adjusted. A better plan would be to measure the distance b when adjusting, and replace the eye-bolt by one turned down to the exact dimensions. In addition, a thin metal casing is generally put round the safety valve, both as an additional safeguard and also for appearance sake. This casing, however, should be well ventilated at the sides so that air can circulate freely round the spring.

3. Reliability is aimed at by keeping the number of levers and joints as small as possible. All pins should be a slack fit, to prevent rusting up. Pockets and places where water can lodge should be avoided, or, at any rate, well drained.

The Total Heat of Saturated Steam.*

For many years Regnault's was the classic formula, now 61 years old, which gives as the total heat of saturated steam—

$$H = 1091{\cdot}7 + 0{\cdot}305\,(t - 32)\ \text{B.T.U.}$$

Nevertheless, the remark is becoming common in the literature of engineering research that such and such a method cannot be used because of the well-known errors in the steam table. It is therefore fortunate that, at least in the range from 32 to 212°, physicists have recently provided a considerable number of good observations of the total heat of saturated steam apparently not noticed by the makers of our steam tables. It is equally unfortunate that, in all these years, there seems to have been not a single new observation above the boiling point. The author shows that certain observations recently made for very different purposes can be combined to give a better set of values of H above 212° than do Regnault's direct measurements, and proposes a new formula for the range from 212 to 400°, the accuracy of which is believed to be something like 0·1 per cent. If these results are correct, Regnault's formula is too high by more than 18 B.T.U., or 1·7 per cent. at 32°; too low by 6 B.T.U., or 0·5 per cent. at 275°; and too high again above 380°, the error increasing rapidly at high temperatures.

The best available value of H_{212} seems to be 1,150·3 mean B.T.U., which is the average of the values of Henning and of Joly. The total heat equation becomes

$$H = 1150{\cdot}3 + 0{\cdot}3745\,(t - 212) - 0{\cdot}000550\,(t - 212)^2$$

The range of this formula is from 212 to about 400° Fah. The greatest error in Regnault's formula in this range is 6 B.T.U., at 275° Fah., but if Regnault's formula is extrapolated to higher temperatures, the error in it increases very rapidly. Below 212° there is an abundance of modern data to show that Regnault's formula runs high, the error reaching 18 B.T.U. at 32°.

Recomputed values of the specific volume of saturated steam differ from the standard values by 101 cub. ft. or 3 per cent. at 32° and by about 1 per cent. in the opposite direction at 275°. Computed values of C_p at saturation agree strikingly with Knoblauch's values, and give additional confirmation to a conclusion already presented to this Society that of the three available sets of C_p values, Knoblauch's, Thomas' and Heck's, Knoblauch's is most deserving of confidence.

A steam table based on these new values will presently be published under the joint authorship of Professor Lionel S. Marks and the present writer.

* By Dr. Davis, "Proceedings American Society Mechanical Engineers," December, 1908.

A Salvage Ship for Submarines.

By Dr. A. GRADENWITZ.

THE German Navy, owing to the frequent accidents that have recently occurred in connection with submarines, ordered from the Howaldtswerke, of Kiel, a salvage ship capable of keeping track of all submarines during the manœuvres, in order to lend immediate assistance wherever required, and to carry out any repairs that may be found necessary.

This salvage vessel, which has recently been completed, is made up of two self-contained pontoons, connected together by transverse beams at the front and rear ends, so as to form one substantial vessel. Those girders are so arranged as to allow the water to stream freely through the intermediary space between the pontoons.

A frame carrying the tackle for the lifting of submarines is installed in the middle of the longitudinal axis of the vessel. This frame consists of four curved framework girders combined in pairs by transverse beams, which girders are spanning the intermediary space between the pontoons, their resting points being riveted to the side walls of the latter. Substantial ribs of special shape ensure a uniform transmission of forces to the walls of the vessel. A further mutual connection of the two pairs of girders is effected by longitudinal girders which, at the same time, serve for carrying the pilot-house and conning tower.

The submarines to be docked are supported by beams turning in pivots on one of their sides; these beams can be fixed by a special device longitudinally or transversely to the vessel.

Being fixed alternately to either of the two pontoons, the beams are used, not only for supporting the docked boats, but for propping the pontoons and connecting them with one another, while imparting an increased resistance to the curved frames, which are open at the bottom.

After the submarine has been lifted out of the water, the beams, which had been arranged longitudinally, are swung round and fixed in position, after which the submarine (with the dead wood underneath) is installed on the girders. The lifted boat then rests with perfect safety in the docking vessel, and can be conveyed along with the latter even in a rough sea. Comfortable passage-ways are provided on the top, inside of the pontoons.

After being repaired, the submarine is again lowered into the water.

As regards the docking of the salvage vessel itself, this differs from the usual process in so far as centre keel pawls, as provided exclusively in most docks, cannot be used, so that special slips have to be placed below the side keels. This is why not all floating docks are suitable for berthing this vessel.

The plans for this salvage vessel have been designed by Herr von Klitzing, whose task was rendered the more difficult as there was no practical experience with similar vessels to fall back upon, while the effects exerted by a rough sea on the cross-connections of the vessel could not be ascertained directly. In order not to put the pivots of the rotating beams to excessive strain on the submarine being introduced, a special device has been provided for completely relieving the upper pivot as soon as the beam has been swung round and connected to the opposite pontoon.

Special interest attaches to a number of arrangements provided in this remarkable vessel; the engine plant, in accordance with the design of the vessel as a system of two pontoons, consists of two identical installations. The two propellers are driven by two electro-motors, for each of which there is a

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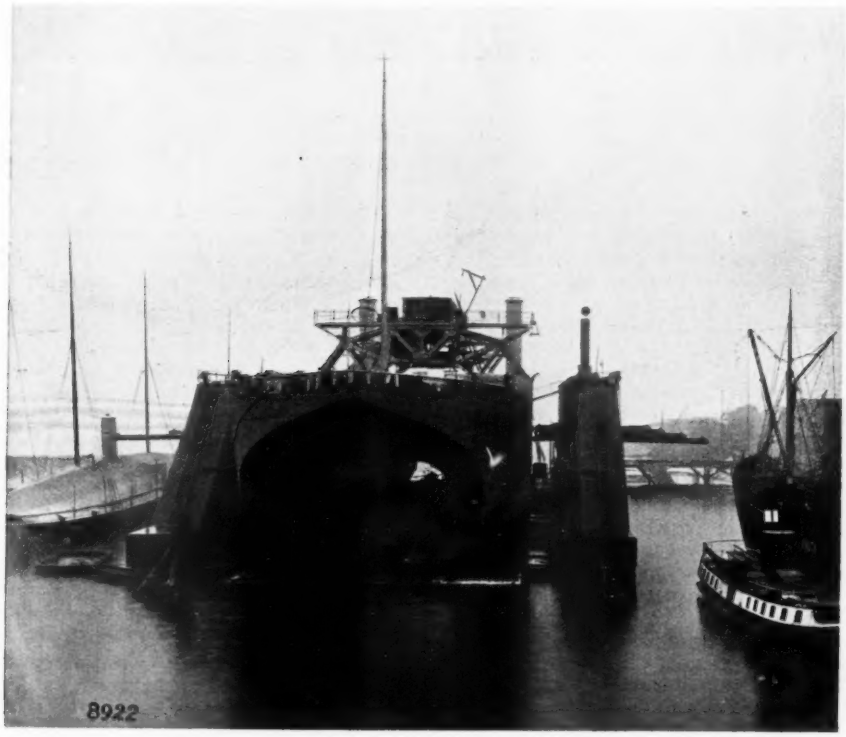

SALVAGE SHIP FOR SUBMARINES.

special source of power arranged in a compartment separated from the motors. However, the same source of power can be as well made to feed both motors, which is specially suitable in the case of low speeds. Each power plant installation comprises a steam turbine, which is directly coupled to a continuous-current machine excited by a dynamo mounted on the same shaft. Another identical machine on the same shaft serves for feeding the propeller motor, which is started from the power plant or the conning tower through a device allowing the motors to be run either both forwards or backwards, or forward and backward respectively.

The boiler plant comprises four water tube boilers, designed on the "Mehlhorn" system, in which the heating gases and boiler water are guided approximately according to the back-current system. A double-action wet-air pump with simplex steering, and a double-action dry-air pump, are provided in each engine-room for operating the condenser plant.

The tests made on this salvage vessel have given very satisfactory results.

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Superheated Steam and Superheaters.

The Author deals with the subject from the point of view of the steam user, and shows in a simple manner the economies effected by superheating. He also points out a few of the faults which may exist in some types of apparatus, and the remedies. The appendix contains some interesting historical notes on superheaters. (Ed. *E.R.*)

PROBABLY at no time in the history of engineering has knowledge on the question of superheating steam been so eagerly sought after as it is at the present time by those who are steam users for commercial purposes.

It would not be correct to say that superheating steam is new to the engineering world, or to say that little or nothing is known or written upon the subject, but it is probably correct to say that little is known to the users of steam power generally to enable them to be able to judge for themselves and form an opinion as to what are the advantages and saving to be obtained by its use.

What has been written has been by men who have devoted much time to the subject, and their results are stated in a manner not readily comprehensible by those who have not had the advantage of a thorough technical training. Among the latter are, unfortunately, a large number of steam users for commercial purposes.

Yet these men surely ought to be catered for since they are directly concerned with the economy effected by superheating.

The main question for the commercial manufacturer is how to get the best result with least expense in proportion to profits; another being a knowledge of the cost of production in detail, in order to find out where waste can be avoided, or where improvement can be made in order to save money in the long run.

At the same time it is impossible for him to be an expert in every branch of his trade, but if he can get to the bottom of each problem in a simple and effective way to give him sufficient knowledge to be able to decide questions as to economy, he has to be satisfied.

Superheating of steam is not by any means new, as will be seen when we find mention of it as far back as 1736; at the same time it would be, perhaps, worth while to say that more has been done in recent years than during the whole of the time previously, because many of the difficulties have been overcome as the result of its having proved a source of great saving.

After their introduction superheaters continued to be more or less used until about forty years ago, after which they rapidly declined in favour, probably owing to the introduction, about that time, of higher temperatures and pressures and their adoption in the compound steam engine. The limit of efficiency having been reached with the latter type of prime mover caused a reversion to superheating, by which a large increase in efficiency is being obtained.

It would be as well to state here that superheating means "adding heat" to any already hot body. It therefore follows that we intend adding heat to the steam in some manner.

As we are dealing here with the production of superheated steam in conjunction with boilers only, it will only be necessary to explain the methods used in this particular case.

Steam generated in a vessel open to the atmosphere is naturally at the same pressure; at this pressure its temperature is constant at 212 deg. F. If steam is generated in a closed vessel and the pressure allowed to exceed that of the atmosphere, then the temperature also increases accordingly, but the temperature for a given pressure is always the same.

Steam, in proportion as its temperature is increased, behaves more and more as a perfect gas when dry, although it

follows no simple law, and if we increase its temperature we must increase either its volume or its pressure owing to expansion.

Every pressure of steam has its definite and corresponding temperature. This temperature is that which will maintain it in the condition of steam, and nothing more. If heat be taken from such steam, some of the steam is condensed, but such abstraction of heat does not produce a lowering of the temperature so long as the pressure is unchanged.

In a boiler plant in ordinary use we have the same pressure both in the boiler and steam-pipes as far as the engine cylinder, but there is nothing around the pipes and engine cylinder to supply the heat that is lost during its travel from the boiler, and so a certain amount, more or less, is condensed to water, according to the conditions prevailing at the place.

Heat does the work in the engine, and steam is the working agent. Therefore if we lose heat we lose efficiency. It is because we have allowed the temperature of the steam to become lowered that its power of useful work is lost.

When steam is generated in a boiler in contact with the water which is in a disturbed state, small particles of water are carried up into the steam space by the steam as it is generated, and it is held there in suspension and carried away into the steam-pipes and on to the engine. This water is the cause of great trouble, as every practical engineer knows, besides being lost power.

Coming back to the steam, we know that the more we can make it expand without condensation the more work we shall get out of it; consequently the drier we can get it the more economical it must prove. To obtain this we must get rid of condensation in the steam-pipes, also of the water in suspension, whether arising from ordinary circumstances or from the boiler being too full of water, or excessive and sudden demands for steam, because all this water takes a certain amount of power to drive it along the pipes, and much efficiency of the steam is lost by passing it through steam traps to separate the water.

Another way in which efficiency is lost is by the variation of temperature caused by expansion of the steam in the cylinder. As pointed out before, lowering heat means lowering pressure. When the action of a piston in a cylinder is followed, we see that as it moves up the cylinder the pressure of the steam is reduced by expansion, consequently the temperature is reduced. This means condensation to form water. The condensed steam is partly re-evaporated by the next inrush of steam, but this robs it of its heat, and so reduces its efficiency of work. This is continually going on at every stroke of the piston, and, in fact, the formation of this film of water on the metal surface of the cylinder constitutes the heaviest loss in the expansive working of steam.

All this is caused by loss of heat, together with the reasons of loss as pointed out previously. Hence it follows that the remedy is to add heat in some way, and so stop the loss. To do this means raising the temperature of the steam above that in the boiler, and so supply it with some heat that it may lose on its way to the engine, in order that it may arrive at and do its work in the cylinder without getting below the condensation point of the pressure at which it leaves the boiler.

The difficulties pointed out above were known in early years of last century, and steps taken then to find a cure or prevention.

Perhaps it will be interesting to name one or two of the principal engineers who attempted this.*

William Congreve was one of the first to try and superheat the steam after it had left the boiler, his idea being to increase its volume, as probably he knew little of the effects upon its pressure. We also have record of attempts with various apparatus by Becker in 1827; Trevithick, about 1830; Raffard, 1848; De Quillac, a year later; Moncheul,

* See also Appendix.

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1850; and chiefly by Hirn in 1855, whose attempts were reported upon in the Bulletin of the Industrial Society of Mulhouse or in that of the Alsatian Society of Steam-users. These attempts and reports were so encouraging to the engineers of Alsace that it made them persevere to such an extent that Germany most probably holds the premier position even to-day in the matter of superheating. John Penn in 1859, B. F. Isherwood in 1854–1860, and Mr. Wethered, also in 1860, made several interesting experiments in England; between 1859 and 1867 Mr. Cornell, Mr. Stone, Messrs. Brow and Cregg, and Carvalho did much to further the cause of superheating.

The result of all these experiments proved that the loss of heat—and consequently pressure and efficiency—which took place by radiation, condensation, &c., could be overcome by adding heat to the steam, which, when sufficient was added, gave even more economical results than had been expected.

It was found that it took very little energy to add heat to the steam in comparison to what it took to form it from water. This action of adding heat to the steam when not in contact with water, and whereby its temperature is raised above that due to its pressure, is called superheating. By superheating, any water that may come from the boiler suspended in the steam or driven along by it is evaporated into steam, and so instead of decreasing the efficiency, it is turned into useful energy. As before pointed out, when heat is added to steam either its volume or pressure is increased. As room cannot be given to allow it to increase in volume, it must increase in pressure, or we can keep it at the same pressure as before with much less fuel to supply the energy required, and also with less violent evolution of steam, or on the other hand do more work with the same amount of fuel.

The questions quite naturally asked are, what are the properties of superheated steam, and how, and why, does it save?

Superheated steam containing no water travels at a greater velocity through any opening than saturated steam and with much less friction, consequently we can get the same energy through smaller pipes, and so do away with much exposed area which causes condensation. It can afford to lose all the added heat without condensing, therefore we get rid of condensation in steam-pipes.

With saturated steam the small particles of water held in suspension get between the faces of the valves, and so leave an opening for the escape of steam. This is especially the case with engines using a slide valve, and means a double loss, because not only is steam wasting, but reducing its efficiency by going past the valve faces, perhaps to exhaust.

The chief item, that of cylinder condensation, is also overcome by superheating. This amounts to a considerable percentage of steam passed into the cylinder; many experts place it as high as 30 per cent., and even more in some cases. It is difficult to give definite figures, because the same conditions do not prevail at every plant; it is safe to say, however, that it is seldom lower than 15 per cent., even in modern plants; in old engines it was as high as 30 per cent., or even 40 per cent. when steam pressures were as low as 20 and 30 lbs. per sq. in.*

* Loss of Steam produced by Initial Condensation in Cylinders.
(W. S. Hutton.)

Type of Engine.	Pressure in pounds of steam used.	Loss caused by initial condensation in cylinder per cent.
Single expansion, or simple stationary engines ...	40 to 100	25 to 60
Portable engines	50 „ 120	25 „ 50
Locomotive engines ...	140 „ 200	20 „ 40
Double expansion, or compound engines	80 „ 120	20 „ 35
Triple expansion engines	150 „ 200	15 „ 25
Quadruple expansion engines	170 „ 220	12 „ 20

Superheated steam would appear to have an advantage over steam-jackets, inasmuch as the heat is applied exactly where it is wanted, and during the period that it is wanted, that is, up to the point of cut-off; whereas a steam-jacket wastes a considerable part of its heat and time in warming up the exhaust.

THE LIMIT OF SUPERHEAT.

The point which no doubt will be followed with great interest is that of the amount of superheat which is most economical and safe to use in modern plants, and about which only recently there has been so much controversy.

With modern engines the total heat* (of steam and superheat) that can be used with safety runs as high as 600 deg. F. (and even 700 deg. F. in especially constructed engines). Thus if we have a steam pressure of 160 lbs. per sq. in. whose temperature is 363 deg., we could add a superheat of 237 deg. to make the total of 600 deg. F.; also with 100 lbs. pressure at 327 deg. F. we could add 273 deg. of superheat. These figures presume that we are dealing with the highest class of engine, but as the majority of engines we find in use are not exactly new, and will consequently not take as high a degree of superheat, we cannot safely expect them to stand more than 450 deg. F. to 500 deg. F.

This will make it appear as if the saving in these cases would not be nearly so high as when a higher degree of superheat can be used with safety.

It will therefore be necessary to point out how the saving is accomplished, and to what degree of heat it is permissible to go.

By a series of experiments extending over many years, both in England and on the Continent, the percentages of saving by superheating, both in steam and coal, have been arrived at by practical and careful tests under almost every possible condition, and in nearly every case the figures are identical for each pressure and temperature for a given amount of work done. The following are the figures arrived at which are plotted as curves on the diagram given on the following page:—

Temperature of steam.	Average steam consumption in lbs.	Average reduction in steam used.
Saturated	14—15	
Superheated 50° F....	13—14	8 per cent.
,, 100° ,, ...	12—13	14 ,,
,, 150° ,, ...	11—12	21 ,,
,, 200° ,, ...	10—11	26 ,,
,, 250° ,, ...	9·5—10·5	30 ,,
,, 300° ,, ...	9—10	34 ,,

As far as the saving in coal is concerned, figures obtained by experts, with many years of experience, such as Prof. Ripper, can be given as a guidance.

These figures have been arrived at by great care and with a great expenditure of time and money, and in all cases are almost identically the same, and after allowing for the heat used in superheating the steam, represent 1 per cent. saving for every 6 deg. of superheat. Thus, 36 deg. give 6 per cent., 72 deg. 12 per cent., 100 deg. F. about 16·7 per cent., and so on.

These figures are only correct providing that all the superheat obtained can be used to advantage. If 100 deg. are obtained and only 70 deg. used, allowing 30 deg. to go to waste (in exhaust or other ways), instead of getting 16·7 per cent. saving we should obtain about 11·7 per cent.

Steam has its greatest energy at the degree closest to its condensation point. It will therefore be best and most economical to let the steam arrive at its work and just emerge at about condensation point,* because if we let some of the superheat out in the exhaust we are working at a loss. (This the writer has actually known to be the case where, when superheating was adopted, the steam raising actually cost more than

* Professor Ripper in his treatise "The Steam Engine in Theory and Practice" gives the total heat (H_2) of superheated steam as the heat required to raise 1 lb. of water at 32 deg. F. to the boiling point (t_1) due to the pressure (p_1); then to convert it into saturated steam at the same pressure; and finally to superheat the steam to some temperature t_2 while the pressure p_1 remains constant. Then—

$$H_2 = H_1 + 0{\cdot}48\,(t_2 - t_1)$$

where H_1 = total heat of saturated steam at pressure p_1.

* If the superheat is sufficiently high to supply not only the heat absorbed by the cylinder walls, but also to provide the heat equivalent of the work done during expansion, then the steam will be dry at release; and this is the condition of maximum efficiency in a single cylinder.

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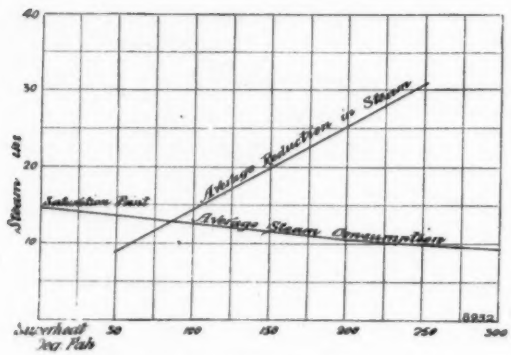

CURVES OF STEAM CONSUMPTION AND REDUCTION DUE TO SUPERHEATING.

before owing to the flue gases being robbed to superheat the steam which passed to exhaust while still superheated, so throwing away more than was saved by its adoption). If any steam is exhausted with a superheat it should be found other work to do, and so get the full value out of it.

To obtain the best result it is almost necessary to have the steam plant inspected by someone with experience in superheating (and this nearly all firms who make superheaters are willing to do and give advice free of cost), and have the superheater made to suit the place it is for and to give the degree of superheat most useful and economical, otherwise the saving of 10 per cent. or upwards, might be a loss of 10 per cent. or downwards.

SUPERHEATERS AND THEIR DIFFICULTIES.

Having obtained some idea about superheated steam itself, it will perhaps be of advantage to turn to the superheater itself and note a few points in its construction and position in relation to the flue and chimney gases.

Undoubtedly for a superheater to work with a boiler from the flue gases of which it has to obtain its heat the best place for the superheater is as close to the fire as possible without, however, the flames playing directly on to it. Consequently in a Lancashire boiler the ideal position is in the downtake at the rear end; for a marine boiler in the uptake above the level of the flue tubes for the return gases; for a water-tube boiler in the space after the flames have passed one set of tubes, or in some similar position.

We must not overlook the fact that it is very desirable for the sake of equality in expansion to have *all* the steelwork composing the superheater in the heat, so as to get the same, or nearly the same, conditions for the whole of the superheater. It is detrimental to have one part comparatively cool and another intensely hot.

All the parts of a superheater need to be made of the best possible material and evenly proportioned throughout, not small masses of metal joining into a larger mass, otherwise the heat expands one quicker than the other and the difference is liable to produce leakage from the joint.

Perhaps it would be as well to state what are the troubles most frequently met with in superheaters.

Many forms of apparatus are composed of tubes of small or large diameter, which are bent in the form of a **U**, the two ends of each tube being expanded into a header, consisting of a box or trough or a steel plate. Bolted to this is the other part of the header which has the inlet and outlet pipes fixed to it. The box header is divided into two separate compartments by means of **a** division; into one compartment one set of tube ends enter, the others passing into the other compartment. The **U** ends of these tubes are suspended in the hot gases, and the steam entering the header goes down one side of the **U** tubes, up the other into the header, and out by the outlet pipe to the main steam-pipe.

The number of these tubes is usually determined by the area of the main steam-pipe, and as the tubes vary as a

general rule from 1 to 1¼ in. internal diameter it is usual to have about 30 to 33 tubes, and upon this the area of heating surface is determined within a limited margin.

These U tubes sometimes prove a source of trouble by their liability to become choked with sediment from the boiler water being carried over, either by priming or by suspension in the steam, and causing in the early stages wire drawing, and later blocking up of the tubes.

Soot also lodges upon the U tubes at the bottom and accumulates there, which tends to lower the efficiency; if these tubes are close together, then the top of U tubes may become covered right across the superheater and cleaning becomes very difficult, so much so that unless the importance of this is emphasised to the flue-cleaners, they leave it undone.

Besides having a larger mass of metal in the header than the tubes in a tubular superheater, which causes unequal expansion, we have the fact that the heat plays on the front and sides of the front row of tubes and sides only of the back row at the top of the superheater; at the bottom the reverse takes place. This may set up uneven expansion in the tubes themselves, and cause them to twist and so lose themselves in the header.

Many superheaters require some space in the flue, and thus occupy a position in which they tend to interfere with the draught. This position also hampers the flue-cleaners in their work.

A further difficulty which is prominent in superheating is the fluctuation of temperature caused by the constant and necessary operation of raking and stoking the fires. During the time that the doors are open for these purposes cold air rushes in and lowers the temperature on the superheater and consequently that of the steam passing through. This is owing to the light build of the superheaters and the quick passage of steam through them. This fault reaches the engine and causes ill effects there also, on account of there not being the body of steam required for the engine to draw upon.

A certain amount of area has to be provided in a superheater for the steam passage, and when this has been provided the degree of superheat is quite dependent on the temperature of the gases playing upon that area; less heating surface cannot be obtained without crippling the steam area; more cannot be got without crippling the draught to a still more serious extent than it already is, so we see that little or no latitude is available for the regulation of the amount of superheat. We have already seen the importance of being able to have only that degree of superheat that we can thoroughly use, or else waste takes place and superheating is no benefit to the steam user.

These do not include all the difficulties in superheater design, but they are the more important. It may be interesting to summarise the points which a good superheater ought to have:—

Means of regulating the amount of superheat; means for cleaning out the sediment; facilities for keeping the joints steamtight; no interference with the draught and preventing proper cleaning of the flues; there must be sufficient metal in its construction and be correctly proportioned in most cases; steam must not pass through too quickly, and there must be sufficient steam space so that the engine has a body of steam to draw upon.

A NEW TYPE OF SUPERHEATER

The following description of an up-to-date apparatus will serve to illustrate some of the foregoing points, and although the example chosen is shown as attached to a Lancashire boiler, it is worth while mentioning that it is also adapted to the requirements of water-tube, marine, and locomotive boilers.

By reference to the illustrations it will be seen that this superheater* is semicircular in shape, and takes the place of the dividing wall. As the apparatus goes down to within a short

* Known as the "Ackroyd and Buckley."

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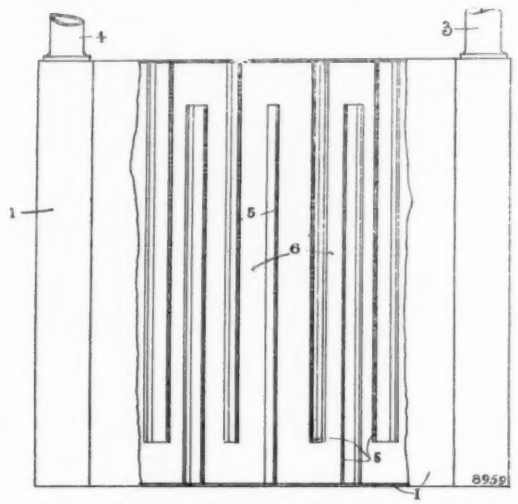

FIG. 1.—PART SECTIONAL ELEVATION OF "ACKROYD-BUCKLEY" SUPERHEATER.

distance of bottom of the downtake and bottom flue; its length is therefore about 8 ft. in most cases. This box or chamber is made of two whole steel plates, and there are therefore no joints in the flue.

The chamber is divided internally by diaphragms of steel, which strengthen the chamber itself, and by being cut short alternately at the top and bottom ends, form a passage for the steam through the whole chamber from inlet to outlet.

The length of time during which the steam remains in a heated chamber determines its temperature, and it is in this way that the temperature of the superheat is regulated. For high superheats more divisions are put in, resulting in the retention of the steam for a longer period within the apparatus, having a greater distance to travel. Fewer diaphragms give less distance, consequently less time, and lower temperature.

The diaphragms are so placed as to leave more area between them than the area in the main steam-pipe, hence it follows that the steam does not flow as quickly through the superheater as through the steam-pipe. This means that it gets more advantage from the superheater than

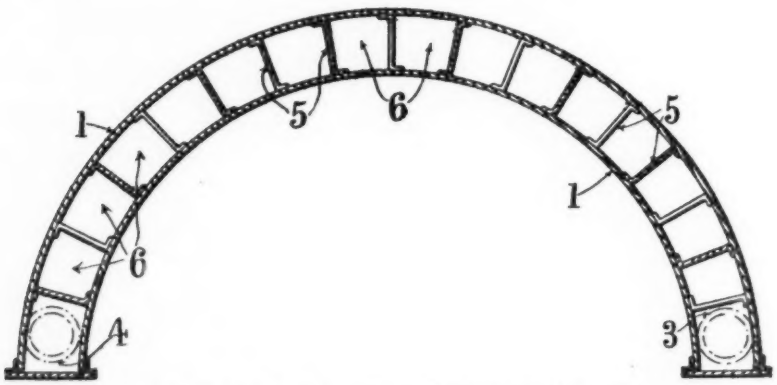

FIG. 2.—SECTIONAL PLAN OF SUPERHEATER, "ACKROYD-BUCKLEY" SYSTEM.

The superheater consists of a vertical b x-like casing (1) of semi-circular shape in plan, fitted up to the back end of the boiler (2); to one end of the casing (1) is attached a steam pipe (3) from the boiler (2), while to the other end of the casing is attached a steam delivery pipe (4). The casing is divided internally by means of division plates (5) alternately cut short at top and bottom, so that steam entering by way of the pipe (3) is caused to pass down and up each alternate chamber (6) in its course to the outlet pipe (4). The gases from the boiler flues play directly on to and over the interior surface of the superheater, then pass along under flue (8) to return along the side flues (9) to the main flue (10), playing on to and over the exterior surface of the apparatus.

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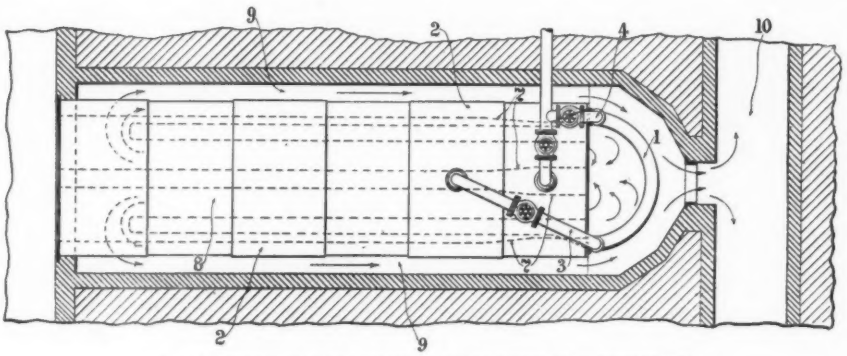

FIG. 3.—SECTIONAL PLAN OF LANCASHIRE BOILER FITTED WITH SUPERHEATER.

if it were passing through at a high velocity. This large steam way also provides the body of steam which is required for the engine to draw upon; also the mass of metal is great and of even thickness practically throughout, which gives even expansion.

In the usual form of apparatus there are 19 diaphragms, and as the superheater is 8 ft. deep and divisions 8 in. apart, we get an area of heating surface equal to 19 × 8 = 152 ft. of 7 in. × 8 in. pipe.

An area equal to two divisions (as the diaphragm is cut short) provides ample space for sediment. At the side of the superheater, near the bottom on the inlet side, is inserted a small mud hole by which all sediment and dirt may be cleaned out without disturbing the superheater or breaking any joints.

No elaborate preparations are necessary for covering up the downtake. The usual way of doing this is with cast-iron covers with a square manhole in the centre for inspection purposes. The whole cover is easily placed in position and the top of superheater forms an excellent bed on which to place it.

COST OF APPARATUS.

Next, and what is an important point, is the cost. This is generally, and rightly so, the main object to a steam user. He must know that the installing of superheaters are useless to him unless they can show a money saving.

The cost of superheaters varies from £90 upwards. Many of the experts on superheating have placed the figure of £180 as a sum for which a really good superheater ought to be had with its accessories (valve, etc.).

For the benefit of those interested in prices I give a few figures as to cost and saving by the adoption of superheaters for an average boiler. We will assume that we can use 100 deg. F. of superheat, which is a common figure, and take the life of a superheater as ten years.

Let the coal consumption slightly exceed 60,000 lbs. per week, say 27 tons, with a boiler supplying steam to an engine developing 250 I.H.P., during a period of 66 hours per week. Assume the coal at 6s. per ton delivered, this will cost £420 per annum.

We have said that 100 deg. F. of superheat should save us 16·75 per cent.; we will assume this at 12 per cent.

Taking the cost of the superheater and fixing at £150.

As the superheater saves 12 per cent., we get a saving on £420 of £50 per annum on coal account.

Assuming the ten years' life, the saving in that time would reach £500.

£50 × 10 = £500
Deduct cost of superheater £150

and the balance remains of £350

If we now divide this net saving by the ten years' life we get £35 per annum saved on £150 outlay, which is equal to more than 23 per cent. per annum over and above the amount paid for the apparatus.

APPENDIX.

Some Historical Notes on Superheaters.

The idea of employing superheated steam dates back to the time when steam engines first reached the industrial stage. While admitting the truth of this statement, many well authorised to judge hold the opinion that the introduction of the system in practice was relatively recent and should be attributed to Hirn (1856). Such opinion, however, is not held by M. Mallet who, in the course of a profound and interesting series of papers presented to the French Society of Civil Engineers, examines the question at some length. In tracing the origin and development of the problem of superheating, M. Mallet describes many forms of apparatus which, by reason of their importance and interest, are reproduced below, together with some extracts from his paper.

The fact that steam, withdrawn from contact with the water from which it was generated, behaves in the manner of a gas in expanding and contracting as its temperature rises or falls within certain limits, appears to have been known for some time. Although it is stated that Papin in 1705 experimented with a mass of iron heated to redness introduced in the piston in order to expand the steam in the cylinder, many contemporary British writers attribute to James Watt the first idea of employing these properties of steam in the engine itself. The claim is probably based on the patent taken out by Watt in 1769, in which he proposes to employ a degree of cooling insufficient to condense the steam, but capable of reducing its volume. As contraction by cooling can only be effected in the case of superheated steam, M. Mallet admits that it was steam in this state that Watt probably had in view, although it is doubtful whether the latter ever made practical use of his claim.

It would appear that in connection with the idea of first employing superheated steam much credit should be given to one Philip Lebon, to whom is ascribed the honour of inventing gas lighting.

According to a French patent, dated 1796, this investigator proposed to use a centrally fired boiler, steam from which was passed through a tube heated to incandescence, to secure the fullest expansion.

Sir William Congreve is mentioned in some quarters as deserving some consideration to the claim of having put forward the earliest idea of employing superheated steam after its formation in the boiler, but the patents relating to steam cited are, according to M. Mallet, too vague to attach much importance thereto, and in any case he was anticipated by twenty years in the case of Lebon.

In 1824 Jacob Perkins proposed and constructed several boilers of novel design in which the double effect of evaporation and subsequent superheating was secured, but it was not until 1826 that James Neville employed a separate superheater in connection with tubular boilers.

Omission must not be made of a patent awarded to one Becker of Strasbourg about the same period (1827). In his apparatus (Fig. 1) steam was produced instantaneously. The water, after having been pumped into an air reservoir, left the latter in a continuous stream to traverse a tube in which it was heated to a high temperature, then entered the generator tubes in which it was instantaneously evaporated; and as soon as formed the steam was led to an externally heated collector in which its temperature was still further augmented.

It is stated by several authorities that in 1828 John Ericsson employed a superheater on a steam-boat for use on the Regent's Canal, and in the course of a discussion at the Institution of Civil Engineers* Cowper stated that in 1834-5, during his apprenticeship at Braithwaites, London, he assisted in experiments conducted on a machine of 24 h.p. made by Ericsson, and fitted with a superheater giving temperature much higher than those actually employed at that date (1860). The results obtained were very favourable, but the system was not extended by reason of certain difficulties connected with the details of the apparatus.

At this period (1828) the "steam chimney" of J. Allaire was introduced, and subsequently found many applications on steam-boats in the United States. At the base of the chimney was an envelope forming a circular space divided into vertical compartments in which the steam circulated before entering the cylinder.

Trevithick's attention was also directed about this time to the subject, resulting in a patent (1832) for a tubular boiler in which a series of "dry pipes" was used for superheating the steam.

Space will not permit us to follow M. Mallet fully in his detailed examination of the various systems proposed, patented, or tried, but the more important may be with advantage reproduced.

The "Cavé" superheater (Fig. 2), constructed in 1855 for the engines of the ships

* 27th May, 1860

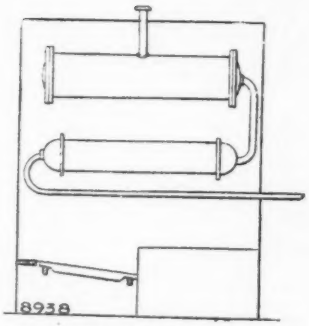

FIG. 1.—THE "BECKER" APPARATUS (1879).

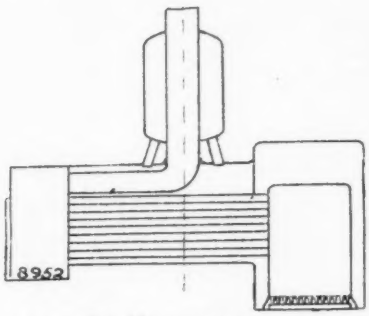

FIG. 2.—"CAVÉ" SUPERHEATER FOR MARINE ENGINES (1855).

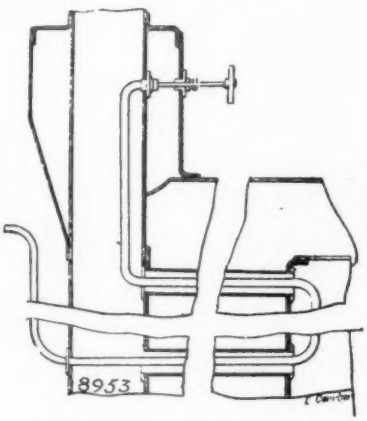

FIG. 3.—THE "WETHERED' SUPERHEATER OF THE STEAMSHIP "JOSEPH JOHNSON" (1854).

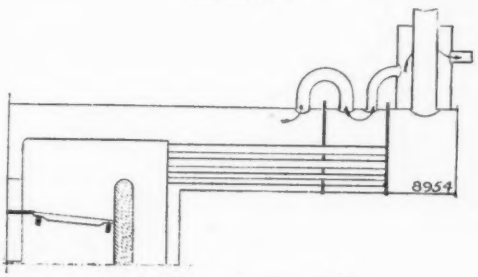

FIG. 4.—"EMORINE" APPARATUS (1855).

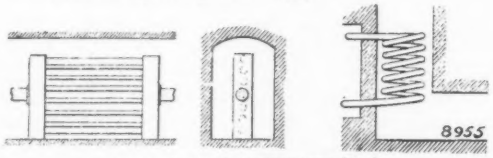

FIG. 5.—"BÈDE" SUPERHEATER (1854).

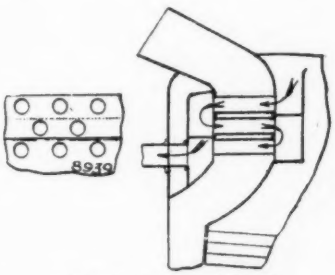

FIG. 7.—DRYING TUBES (1855–6).

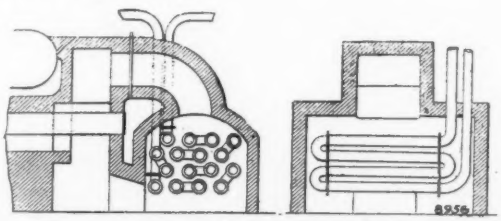

FIG. 6.—"HIRN'S" SUPERHEATER (1855).

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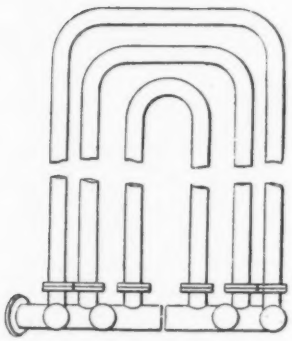


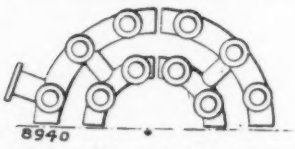


FIG. 8.—"DELAFOND" SUPERHEATER (1858).

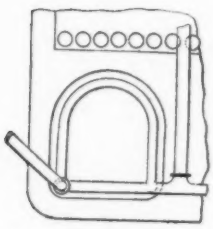


FIG. 9.—"PARSON AND PILGRIM" SUPERHEATER (1858).

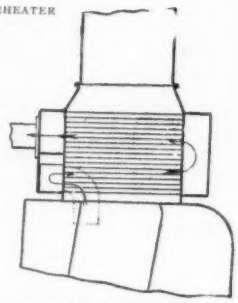


FIG. 10.—"BEARDMORE" SUPERHEATER (1858).

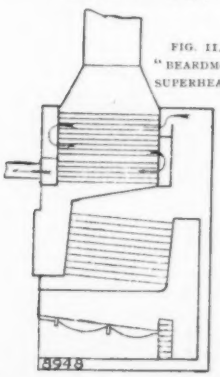
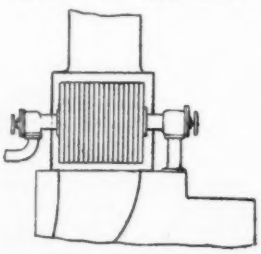


FIG. 11.—"BEARDMORE" SUPERHEATER.

FIG. 12.—VERTICAL SUPERHEATER.



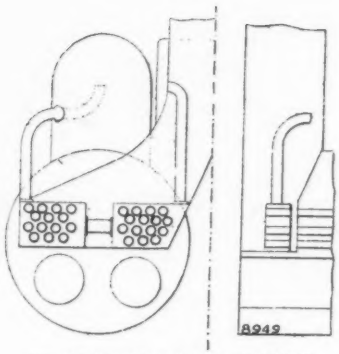


FIG. 13.—"PATRIDGE" APPARATUS (1858).

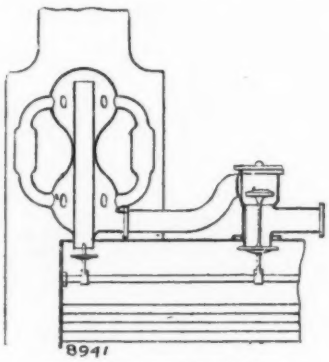
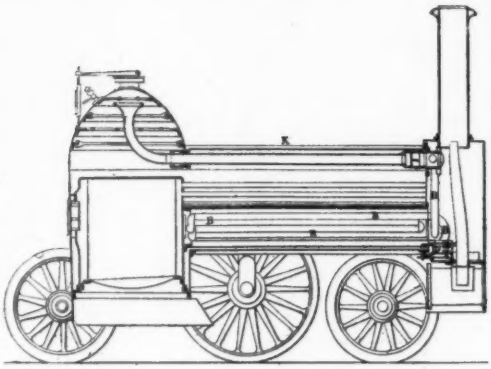


FIG. 14.—"JAFFREY" SUPERHEATER.

Ville de Bordeaux and *Ville de Brest*, is of interest.

The boilers employed were of the horizontal locomotive type, working at high pressure, surface condensing, the steam being dried and slightly superheated in a reservoir surrounding the chimney.

The "Wethered" superheater (Fig. 3) marked an important development in superheating. It was first employed (1854) in a Hudson River paddle-wheel tug boat, the engine of which consisted of a single cylinder, steam being supplied by a return-tube type boiler. The superheater tubes, taking steam from a chamber at the base of the chimney, passed through the flue



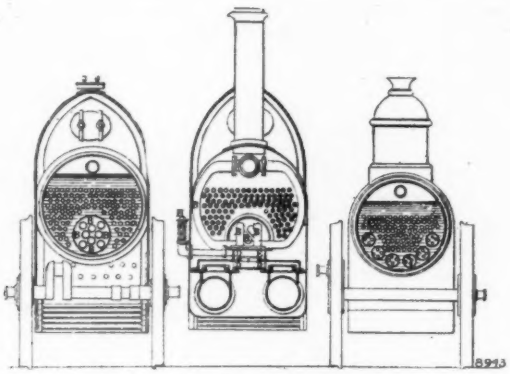


FIG. 17.—"MONCHEUIL" SUPERHEATER.

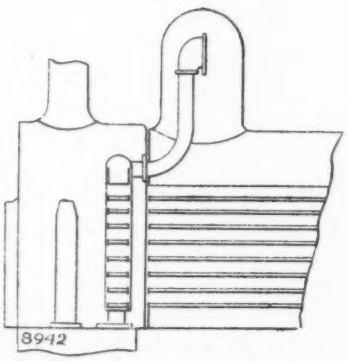


FIG 18.—MACCONNELL'S SUPERHEATER (1852)

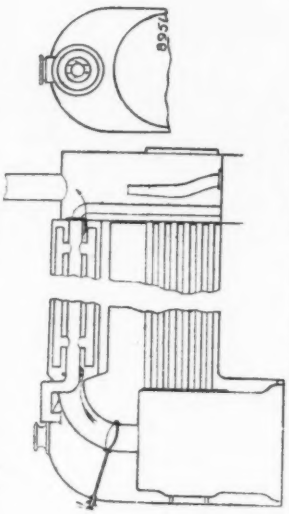
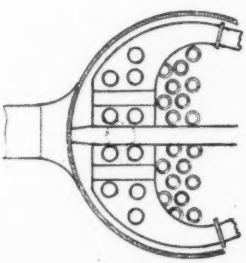


FIG. 16.—"MONCHEUIL APPARATUS (1850).

FIG. 15.—"HAWTHORN" SUPERHEATER.



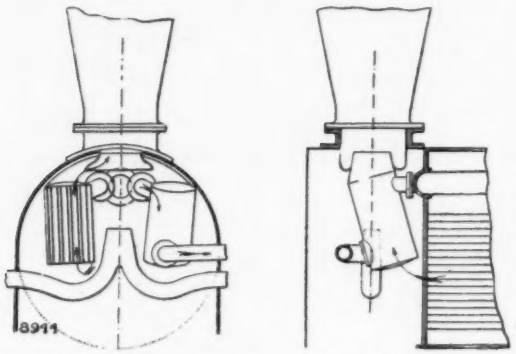


FIG. 19.—"MARTIN" SUPERHEATER (1860).

tubes and left the boiler just above the fire-box doors. Trials carried out with this apparatus gave an economy of 33 per cent.,* a result sufficiently satisfactory to lead to important applications on the Transatlantic liner *Arctic* of the Collins line, the Admiralty yacht *Black Eagle*, the transport *Dee*, the *Rhadamanthus*, and the Royal Mail liner *Avon*.

Fig. 4 is an apparatus patented by d'Emorine (1855), consisting of a tubular boiler in which the superheater is constituted by a prolongation of the tubes into a space enclosed by the boiler shell and two tube plates into which steam from the boiler passes on its way to the engine. Another invention taken out in the same year by Bède, of Liege, is illustrated in Fig. 5, in which the tubes used were of copper.

Hirn's original apparatus (1855), shown in Fig. 6, consisted of sixteen cast-iron tubes and elbows placed horizontally in a chamber connected with an elephant boiler. Valves were used to admit the hot gases to the tubes, thus providing a means of regulating the temperature of the outgoing steam.

Drying tubes (Fig. 7) had a vogue at about this period in the French marine, but they were ultimately abandoned on account of the difficulties arising in connection with inspection and repairs, the apparatus forming an integral part of the boiler. They gave way to an independent apparatus connected with the boiler by tubes, so that separation could be readily effected when desired.

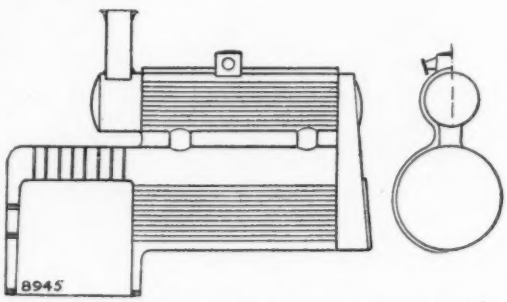


FIG. 20.—SUPERHEATER, NORTHERN OF FRANCE RAILWAY (1863).

The "Delafond" (Fig 8) is a type of this apparatus, consisting of iron U tubes mounted on the crown of the boiler at the base of the chimney.

Marine superheaters have taken many different forms, but they may be divided into two distinct classes: those employing the direct heat of the furnace or tubes, and those employing waste heat. Among the former may be mentioned the "Wethered" apparatus employed on the *Joseph Johnson* in 1854, and mentioned above, and the "Parson and Pilgrim" apparatus (Fig. 9), placed in the furnace. In the second class may be placed the drying tubes already referred to, the "Beardmore" horizontal tube superheater

* Murray, "Treatise on Marine Engines." Ed. 1858.

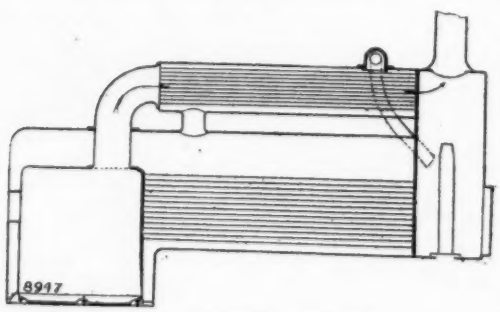


FIG. 21.—"HITTORF" SUPERHEATER.

(Figs. 10 and 11), superheaters of the vertical tube type placed at the base of the chimney (Fig. 12), and the apparatus shown in Fig. 13 composed of tubes placed as a prolongation of the boiler tubes and traversing a narrow chamber placed in the smoke-box.

An interesting example is the "Jaffrey" apparatus (Fig. 14), much in vogue at one period on vessels constructed on the Tyne. Notice the disposition of the valves, permitting the use of either saturated or superheated steam.

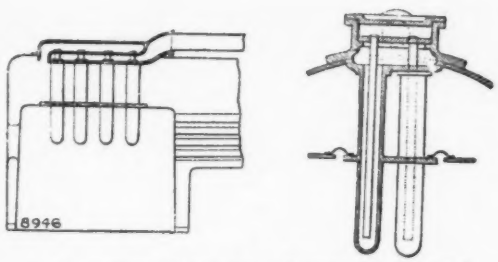


FIG. 22.—ANOTHER ARRANGEMENT OF "HITTORF" SUPERHEATER (1863).

APPLICATION TO LOCOMOTIVES.

The first indication of the employment of a superheater on a locomotive is due to John Hawthorn, whose patent (1840) provides for several dispositions of the apparatus, the most interesting being that shown in Fig. 15, consisting of a box placed in the upper portion of the smoke-box and traversed by a series of both vertical and horizontal tubes, through which passed the hot gases on their way to the chimney. At a meeting of the Institution of Civil Engineers* one of the speakers referred to an engine of the Great Western Railway that was fitted with a superheater fifteen years previously, the experiment not proving, however, successful. It is probable that the "Hawthorn" apparatus was referred to.

The "Moncheuil" superheater is shown in Fig 16. This dates back to 1850, and consists of a large conduit, fitted with a register, through which passed a portion of the hot gases direct from the fire-box, to a horizontal cylinder placed above the upper surface of the boiler, and containing the tube conducting steam from the dome to the cylinders. Another arrangement is shown in Fig. 17. A large tube is disposed in the lower portion of the boiler, and contains another tube folded back on itself several times and in which the steam circulates. As a variant this large tube may be replaced by four smaller tubes, also containing superheater tubes. an arrangement which is almost identical in principle with the Schmidt superheater, in extensive use to-day on Continental locomotives. The "Moncheuil" superheater was extensively tried on a locomotive of the Lyons railway without, however, leading to any important result.

* 27th March, 1860.

A little later on MacConnell, the locomotive superintendent of the L. & N. W. Railway, protected a superheater of the form shown in Fig. 18. It consists of a chamber located in the smoke-box and containing tubes corresponding to those of the boiler itself, about which played the hot gases. According to the *Illustrated London News*, some of the locomotives of this company were fitted with the apparatus.

The apparatus shown in Fig. 19 was designed by J. Martin in 1860, and applied on several locomotives of the Grand Trunk Railway. It consisted of two parts placed one on each side of the smoke-box, and each made up of a cylindrical body traversed by a number of superheater tubes. The main steam-pipe from the regulator led by bifurcations to the superheaters, the steam passing therefrom to the cylinders by two other tubes. A model of this apparatus was shown at the Great Exhibition of 1862. About this period the Northern Railway of France fitted a number of their locomotives with an apparatus of the type shown in Fig. 20. It was composed of a bundle of horizontal tubes placed above the boiler, and through which the gases after leaving the boiler tubes passed, the superheater tubes being enclosed in a steam space in which steam passing from the boiler to the cylinder circulated.

In 1863 a German engineer, Hittorf, proposed the two arrangements shown in Figs. 21 and 22. The first comprises a number of tubes placed above the boiler, and heated not by the smoke-box gases, but directly from the fire-box, the quantity of gases so drawn off for the purpose of superheating being regulated by means of registers. The second arrangement was made up of tubes set vertically in the fire-box as shown, containing inner steam tubes leading into an upper rectangular chamber connected with the main steam-pipe.

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The revival of superheating in 1898 on the Prussian State Railways, who adopted the system of Schmidt, set up a rapid development of the system on the Continent, no less than 2,728 locomotives belonging to different administrations being so fitted. This type of apparatus has, however, already been dealt with in these columns. On a less extensive scale other systems are to-day in use, of which mention may be made of the "Pielock," "Clench-Gölsdorf," "Cole," "Vaughan" and "Vandain," the last three being used in America.

Some Possibilities of the Gas Turbine.

By F. C. WAGNER.

In considering the possibilities of a gas turbine it has commonly been assumed that the gas should be burned with something near the theoretical quantity of air required for complete combustion, as is done in the explosion gas engine of the ordinary type. Under this condition the temperature of the gases when they strike the turbine wheel is so high that the metal of the wheel reaches a temperature at which its strength is seriously diminished.

It may be possible to pass water through the turbine wheel and keep down the temperature of the body of the wheel. But the blades, being long and thin, would become much hotter than the body of the wheel, and to pass water through the blades themselves would complicate the construction of the wheel enormously.

Two methods of reducing the temperature of the gases themselves are possible. One method is to use an excess of air in burning the gas or gasolene, sufficient to keep the temperature of the gases after expansion in the nozzles within safe limits. The other method is to inject a liquid, preferably water, into the gases. The liquid absorbs heat, becoming superheated vapour, and the vapour furnishes work during expansion. It is the purpose of this paper to compare the above methods of reducing temperature of the gases, and especially to consider how such comparison is affected by variations in the efficiencies of the turbine and the air compressor.

The cycle of the type of gas turbine here considered is similar to that of the Diesel engine. The air is first compressed up to the maximum pressure. Fuel, either gas or oil, separately compressed, is then introduced and burned under pressure. The volume of the air is thereby expanded at constant pressure. After the burning is completed the hot gases expand adiabatically and the pressure drops. In the Diesel engine the expansion is incomplete, while in the gas turbine the expansion may be complete down to atmospheric pressure.

The efficiency of the above cycle may be readily found if both compression and expansion be assumed to be adiabatic. Let T_4 be the absolute temperature of the air just before compression; T_1 the temperature at the end of the compression; T_2 the temperature when the combustion is just completed; and T_3 the temperature at the end of the expansion. Assume the expansion to be complete. Then the ratio of the pressures at the extremities of an adiabatic change, sometimes called the compression pressure ratio, is the same for the expansion line as for the compression line. Denote this ratio by ρ. Let $C\rho$ denote the specific heat of air at constant pressure, and γ the ratio of the specific heats.

Since the net mechanical work done equals the difference between the heat absorbed and the heat rejected during a complete cycle, it follows that the efficiency can be expressed thus:—

$$Eff. = \frac{C\rho\,(T_2 - T_1) - C\rho\,(T_3 - T_4)}{C\rho\,(T_2 - T_1)}$$

$$= 1 - \frac{T_3 - T_4}{T_2 - T_1}$$

From the adiabatic relation,

$$\frac{T_1}{T_4} = \frac{\gamma - 1}{\rho\gamma} = \frac{T_2}{T_3}$$

Consequently,

$$Eff. = 1 - \frac{T_4}{T_1} = 1\,\frac{1 - \gamma}{\rho\gamma}.$$

The interesting feature of this expression for efficiency is that the theoretical efficiency

depends only upon the ratio of compression. It does not depend on the maximum temperature reached. Consequently, from a theoretical standpoint, it makes no difference whether the fuel is burned with the theoretical amount of air or with a considerable excess. If a sufficient excess of air is used the temperature of the gases when they strike the turbine blades can be brought down to a value for which the strength of steel retains a high value.

When practical efficiencies are considered, however, it is found that the proportion of air to fuel becomes important. Of the theoretical power that can be developed only a fraction is actually converted into mechanical power. Consequently a much larger proportion of the available power must be consumed in compressing the air than is allowed in the theoretical expression for efficiency. The greater the proportion of air to fuel the more will the practical efficiency fall off from the theoretical. The question arises whether with practical mechanical efficiencies for the turbine and the compressor a sufficient excess of air can be used to bring down the temperature of the gases to a proper value and still give a reasonable efficiency for the complete operation.

The velocity stage type of turbine seems best suited for use as a gas turbine. The gases may be expanded completely in a nozzle of refractory material down to their lowest temperature before striking the wheel. The calculations which follow will be limited to this type of turbine.

The formula for theoretical efficiency indicates that high compressions are favourable to efficiency. To produce high compressions it is practically necessary to use two-stage or three-stage compressors. It occurred to the writer that it might be an advantage to use intercoolers between the stages of such compressors. Calculations have accordingly been made for the purpose of comparing the efficiencies obtainable with intercoolers and without them, with the general result, as shown in the tables, that while theoretically the best efficiency is obtained by adiabatic compression without intercoolers, yet with such values as are practically obtainable for the mechanical efficiencies of turbine and compressor the use of intercoolers is decidedly advantageous.

Calculations have been made for a two-stage compressor having total compression pressure ratios of 9 and 16, and for a three-stage compressor with a ratio of 27. The letter *a* is used when the compression is completely adiabatic, the letter *c* when the compression is adiabatic in each stage but the air is cooled between stages, and the letter *w* when water is injected.

It is assumed that the temperature of the air entering the compressor is 531° F. abs., and also that each intercooler reduces the air to 531° abs. The pressure of the air at the beginning of the compression is assumed to be 14·7 lb. per square inch abs., and the temperature of the gases leaving the expanding nozzle is assumed to be 1,200° F. abs., at which temperature the tensile strength of steel is about 10 per cent. less than at ordinary temperatures. It is assumed that the fuel used is a gasolene containing 15 per cent. hydrogen and 85 per cent. carbon, and that its calorific value is 20,000 B.T.U per pound. The work required to force the gasolene into the compressed air is relatively small and has been neglected. The value of γ taken was 1·4 for the air during compression. For the gases during expansion γ has been taken as 1·39. The value of the specific heat at constant pressure is taken as 0·2375 for the air and 0·25 for the gases.

The following is a sample calculation for a two-stage compressor with a pressure ratio of 3 in each stage:—

Maximum pressure = 14·7 × 9 = 132. 3 lb. per sq. in.

(*a*) $T_1 = T_4 \times \frac{3}{9} = 531 \times 9^{\frac{2}{7}} = 995°$ abs.

(*c*) $T_1 = 531 \times 3^{\frac{2}{7}} = 727°$ abs.

$T_3 = 1{,}200°$ F. abs.

$$T_2 = 1{,}200 \times \frac{\cdot 39}{9^{\cdot 39}} = 2{,}225°.$$

(*a*) Heat given to 1 lb. of gases = ·25 (2,225 − 995) = 307 B.T.U.

Gas used per lb. of air = 307/20,000 = 0·015 lb.

Heat given to 1·015 lb. of gases = 312 B.T.U.

(*c*) Heat given to 1 lb. of gases = 0·25 (2,225 − 727) = 374 B.T.U.

Gasolene used per lb. of air = 0·019.

Heat given to 1·019 lb. of gases = 381 B.T.U.

(*a*) Heat equivalent of work required to compress 1 lb. of air = 0·2375 (995 − 531) = 110 B.T.U.

(*c*) Heat equivalent to compress 1 lb. of air = 0·2375 (727 − 531) × 2 = 93 B.T.U.

(*a*) Heat equivalent of work derived during expansion of 1·015 lb. of gases = 1·015 × 0·25 (2,225 − 1,200) = 260 B.T.U.

(*c*) Heat equivalent of work derived during expansion of 1·019 lb. of gases = 1·019 × 0·25 (2,225 − 1,200) = 261 B.T.U.

(*a*) Heat required to vaporize 0·015 lb. of gasolene and heat it from 531° to 995° = [·5 (995 − 531) + 240} × 0·015 = 472 × 0·015 = 7 B.T.U.

(*c*) Heat required to vaporize 0·019 lb. of gasolene and heat it from 531° to 727° = 0·019 × [0·5 (727 − 531) − 240] = 338 × 0·019 = 6 B.T.U.

(*a*) Theoretical efficiency $= \frac{260 - 110}{312 + 7} = 0{\cdot}47.$

(*c*) Theoretical efficiency $= \frac{261 - 93}{381 + 6} = 0{\cdot}43.$

For a mechanical efficiency of the turbine of 0·65 and of the compressor of 0·85 the combined efficiencies will be:—

(*a*) Eff. $= \frac{0{\cdot}65 \times 260 - 110 \div 0{\cdot}85}{319} = 0{\cdot}13.$

(*c*) Eff. $= \frac{0{\cdot}65 \times 261 - 93 \div 0{\cdot}85}{387} = 0{\cdot}16.$

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The corresponding calculation for water cooling follows. The heat absorbed by the injected water has been calculated from the values for the specific heat of superheated steam given in a recent paper by Professor Thomas.*

Temperature at end of compression (a) = 995°.
Temperature at end of compression (c) = 727°.
Allow 19 lb. of air to 1 lb. of gasolene.
Theoretical temp. of gases after burning

$$(a) = \frac{20{,}000 - 472}{20 \times \cdot 25} + 995 = 4{,}900°.$$

Theoretical temp. of gases after burning

$$(c) = \frac{20{,}000 - 338}{20 \times \cdot 25} + 727 = 4{,}659°.$$

Temperature at beginning of expansion = 2,225°.
B.T.U. required to convert 1 lb. of water at 70° F. into superheated steam at 2,225° and 132·3 lb. pressure = 1,188·2 − 38 + 142 + 0·47 (2,225 − 1,079) = 1,830.
Water required per pound of gas

$$(a) = \frac{(4{,}900 - 2{,}225) \times 0{\cdot}25}{1{,}830} = 0{\cdot}37.$$

Water required per pound of gas

$$(c) = \frac{(4{,}659 - 2{,}225) \times 0{\cdot}25}{1{,}830} = 0{\cdot}33.$$

Work done by 1 lb. of gas = 256 B.T.U.
Temperature of steam at end of expansion = $2{,}225 \div 0{\cdot}9^{\frac{0{\cdot}3}{1{\cdot}3}} = 1{,}340°$.
Work done by superheated steam (a) = 0·37 × 0·47 (2,225 − 1,340) = 154 B.T.U.
Work done by superheated steam (c) = 0·33 × 0·47 (2,225 − 1,340) = 138 B.T.U.
Heat furnished by $\frac{1}{20}$ lb. of gasolene = 1,000 B.T.U.
Eff. (theoretical)

$$(a) = \frac{256 + 154 - 19/20 \times 110}{1{,}000} = \frac{410 - 105}{1{,}000} = 0{\cdot}305.$$

Eff. (theoretical)

$$(c) = \frac{256 + 138 - 19/20 \times 23}{1{,}000} = \frac{394 - 88}{1{,}000} = 0{\cdot}306.$$

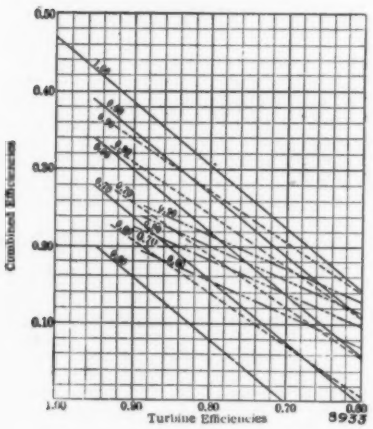

FIG. 1.

$\rho = 9$. Maximum Pressure = 132·3.

* Proc. Am. Soc. Mechl. Engrs., 1908.

A calculation of the total efficiencies for various efficiencies of turbine and compressor shows that a combination of water injection and intercooling gives a slightly higher total efficiency than water injection without intercooling. It is not probable that both would be used in the same machine, and consequently the calculations have been limited to the case of water injection with true adiabatic compression.

The results have been arranged in the form of tables and also plotted in the accompanying diagrams. If the turbine efficiencies be chosen as abscissæ and the total efficiencies as ordinates, then for a fixed compressor efficiency the relation will be expressed by a straight line. Lines have been drawn representing compressor efficiencies of 90, 80, 70, and 60 per cent. Full lines represent cooling by excess of air and true adiabatic compression; dotted lines, cooling by excess of air and cooled compression; broken lines, cooling by water injection and adiabatic compression.

An inspection of these tables and diagrams shows that, for all values of the mechanical efficiencies that seem obtainable at present, true adiabatic compression gives a lower total efficiency than either intercooling or water injection.

It also appears that water injection gives a higher efficiency under some conditions than air dilution, while under other conditions the reverse is true. The diagrams show this very clearly. The slope of the total efficiency lines is such that the total efficiency line for water injection corresponding to a certain compressor efficiency may intersect the line for air dilution with intercooling corresponding to the same compressor efficiency. For instance, in the diagram for a compression ratio of 16, the total efficiency line for water injection corresponding to 70 per cent. compressor efficiency crosses the 70 per cent. line for air dilution with intercooling at 74. Consequently when the compressor efficiency is 70 per cent., the total efficiency for water injection is less than for air dilution with intercooling if the turbine efficiency is greater than 74 per cent. If the turbine efficiency is less than 74 per cent., water injection shows the greater efficiency.

Comparing the diagrams for different compression ratios, not only are the total efficiencies greater for the higher pressures, but the relative effects of the different methods employed for keeping down the temperature of the gases upon the total efficiencies change decidedly. For instance, in the diagram for $\rho = 16$, the 70 per cent. lines for water injection and for intercooling

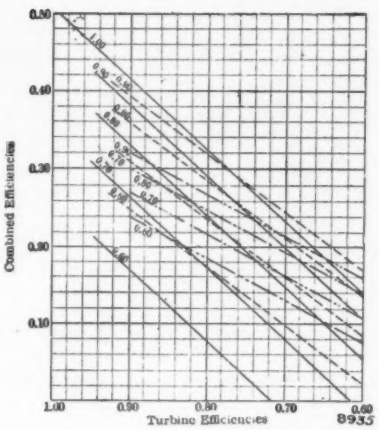

FIG. 2.
$\rho = 16$. Maximum Pressure = 235.

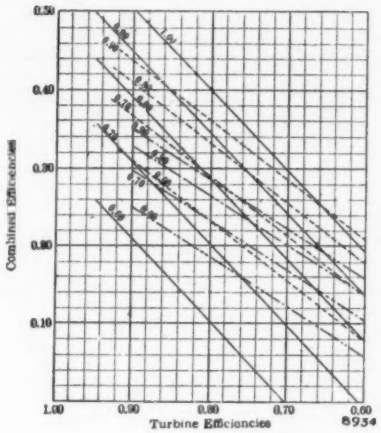

FIG. 3.
$\rho = 27$. Maximum Pressure = 397.

intersect at a turbine efficiency of 74 per cent., while in the diagram for $\rho = 27$, the corresponding lines do not intersect within the limits of the diagram, showing in the latter case that air dilution with intercooling is the more efficient for all values of turbine efficiency included in the diagram.

The air used per pound of gasolene in the different cases is as follows :—

For $\rho =$ 9 condition (a) ...	... 66 lb.
For $\rho =$ 9 condition (c) ...	... 52 lb.
For $\rho =$ 16 condition (a) ...	... 52 lb.
For $\rho =$ 16 condition (c) ...	... 43 lb.
For $\rho =$ 27 condition (a) ...	... 47 lb.
For $\rho =$ 27 condition (c) ...	... 34 lb.
For all values of ϕ (w) ...	... 19 lb.

What can be expected of the gas turbine in practice.

Air compressors of the piston type have been constructed which give a mechanical efficiency of 85 per cent. The best mechanical efficiency obtained with steam turbines is in the neighbourhood of 65 per cent. Whether a velocity stage gas turbine of equal efficiency is possible can only be determined by actual trial. Some of the points of difference are as follows :—

In the steam turbine, the wheel revolves in gaseous mediums varying from a considerable density at the higher pressures to a very small density in the vacuum at the exhaust end. In the gas turbine, the gaseous medium is at atmospheric pressure, but on account of its high temperature the density will be only a little more than a third of that of air under ordinary atmospheric conditions. It is quite possible that the whole friction will be no greater on the whole for a gas turbine than for the best steam turbine.

The velocity of the gases leaving the expansion nozzle for a compression ratio of 27 would be about 4,600 ft. per second, which is much higher than occurs in steam turbine practice. The effect of friction at such high velocities is yet to be determined. The experiments indicate that up to 220 lb. per sq. in. pressure the percentage of friction loss in a properly shaped nozzle diminishes with increase of pressure. If this law continues, the use of high jet velocities may not detract from the efficiency.

It seems, therefore, within the range of possibilities to construct a gas turbine giving an efficiency of 60 per cent., and a three-stage air compresser of 85 per cent. efficiency. Referring to Fig. 3, the combined efficiency for air dilution with intercooling is found to be 19·5 per cent., and for water injection 15 per cent.

Detail tests of engines using petrol and alcohol show that the smallest fuel consumption with gasolene was about 0·7 lb. of gasolene per brake horse-power, obtained only with the most perfect adjustment in a very few tests. The average fuel consumption was nearer 1·25 lb., which probably represents more nearly the average practice. A fuel consumption of 0·7 lb. of gasolene per horse power corresponds to an efficiency of about 18 per cent., while 1·25 lb. corresponds to 10 per cent. efficiency

TABLE 1.—TOTAL EFFICIENCIES FOR VARIOUS MECHANICAL EFFICIENCIES.
$\rho = 9$; Maximum Pressure = 132·2 lb. per sq. in. abs.

Compressor Efficiency.	Turbine Efficiencies.														
	1·00			0·90			0·80			0·70			0·60		
	a	*c*	*w*	*a*	*c*	*w*	*a*	*c*	*w*	*a*	*c*	*w*	*a*	*c*	*w*
1·00	0·47	0·43	0·30												
0·90				0·35	0·34	0·26	0·27	0·27	0·23	0·19	0·21	0·17	0·11	0·14	0·13
0·80				0·30	0·31	0·25	0·22	0·24	0·22	0·14	0·17	0·16	0·06	0·11	0·12
0·70				0·24	0·26	0·23	0·16	0·20	0·19	0·08	0·13	0·14	0·00	0·06	0·10
0·60				0·16	0·21	0·20	0·08	0·14	0·16	0·00	0·07	0·12	0·00	0·00	0·07

TABLE 2.—TOTAL EFFICIENCIES FOR VARIOUS MECHANICAL EFFICIENCIES.
$\rho = 16$; Maximum Pressure = 235 lb. per sq. in. abs.

Compressor Efficiency.	Turbine Efficiencies.														
	1·00			0·90			0·80			0·70			0·60		
	a	*c*	*w*	*a*	*c*	*w*	*a*	*c*	*w*	*a*	*c*	*w*	*a*	*c*	*w*
1·00	0·52	0·51	0·39												
0·90				0·38	0·39	0·32	0·30	0·32	0·26	0·20	0·24	0·21	0·12	0·17	0·16
0·80				0·33	0·36	0·30	0·24	0·28	0.24	0·15	0·21	0·19	0·06	0·13	0·14
0·70				0·26	0·31	0·27	0·18	0·23	0·22	0·09	0·15	0·16	0·00	0·08	0·11
0·60				0·17	0·25	0·24	0·08	0·17	0·18	0·00	0·10	0·13	0·00	0·02	0·08

TABLE 3.—TOTAL EFFICIENCIES FOR VARIOUS MECHANICAL EFFICIENCIES.
$\rho = 27$; Maximum Pressure = 397 lb. per sq. in. abs.

Compressor Efficiency.	Turbine Efficiencies.														
	1·00			0·90			0·80			0·70			0·60		
	a	*c*	*w*	*a*	*c*	*w*	*a*	*c*	*w*	*a*	*c*	*w*	*a*	*c*	*w*
1·00	0·61	0·55	0·43												
0·90				0·45	0·44	0·35	0·35	0·36	0·29	0·24	0·29	0·23	0·14	0·21	0·16
0·80				0·39	0·41	0·33	0·29	0·33	0·26	0·18	0·25	0·20	0·08	0·18	0·14
0·70				0·31	0·37	0·29	0·20	0·29	0·23	0·10	0·21	0·16	0·00	0·13	0·11
0·60				0·21	0·31	0·25	0·10	0·23	0·19	0·00	0·15	0·12	0·00	0·08	0·06

The gas turbine appears to offer advantages in reliability, comparative simplicity of adjustments, and freedom from annoying troubles as compared with the explosion engine. Whether it can compete with the latter in power developed per unit of weight remains to be determined. A further advantage over the explosion engine is that the gasolene turbine can burn crude oil, which is a cheaper fuel.

[Proc Am. Society Mechanical Engineers.]

Electrical Progress

By ANDREW STEWART, A.M.I.E.E.

Electrically Propelled Ferry Boat.

A vessel of this type is now in service on the Rhine between Godesberg and Niederdollendorf. A longitudinal section of the vessel is given (Fig. 1). It is 98½ ft. between perpendiculars, 26¼ ft. beam, with a depth of 6 ft. 3 in. The general arrangement of the space below decks is shown in Fig. 1, from which it will be apparent that the battery is located below that part of the deck which carries the vehicles, four of which, together with 645 passengers, can be carried. The number of vehicles presupposes that they are harnessed horse vehicles; if unharnessed or motor vehicles are carried, about twice this number can be accommodated.

Fig. 2 shows the section of the vessel under the fore-deck where the vehicles are carried, and also a section through the motor room, which contains two 50-h.p. motors, one driving each shaft at 300 revolutions per minute.

The propelling battery consists of 160 cells in vulcanite cases, giving a voltage of about 320. The motors are controlled from the navigating bridge through tramway type controllers, one to each motor, and both motors may be operated simultaneously by means of an interlocking device on the controllers. There is, therefore, no need for any labour in the motor room. In addition to the propelling motor-control gear, there are two other controllers for manipulating two small motors that are used for raising and lowering the gangways, which are shown lowered in Fig. 3; the means by which they are geared and the gangway is counterweighted is clearly shown. These gangways, when raised, form bulwarks. The batteries are charged on the Godesberg side of the river, connection being made by armoured cable.

It is interesting to note from the notice of the storage battery electric railway cars in our last issue, and the foregoing battery propelled ferry boat, that the battery-propelled vehicle or ferry boat is no longer considered the impracticable proposition it once was. The early failures—and most disastrous some of these were—naturally deterred people from making further experiments. During recent years, however, improvements in manufacture have placed the secondary battery on quite a different plane from that which it occupied five years ago. That even now it makes practicable the operation of heavy road vehicles in competition with other forms of propulsion, we doubt, but the limitations of the secondary battery are no longer as well defined as formerly, and there is considerable scope for their use, especially if operated under conditions which free the battery from the serious deterioration due to vibration, jerks, and heavy overloads. That the Edison accumulator will still further extend the field of the storage battery vehicle there can be no doubt whatever.

Some Data on Electrically Produced Steel.

As our readers are aware, electrically produced steel is now a commercial product, though it is generally confined to special steels of high market value. In some countries where fuel is costly it pays to produce even lower grade steels by this means. The electric furnace is, under such circumstances, almost the only economical method of dealing with iron in process of conversion into steel, and the development of water-power stations, provided, of course, that the capital cost of so doing is not excessive, may bring countries that are not well situated for the cheap supply of coal into competition with countries that are more favourably situated in this respect.

An example of a furnace producing not

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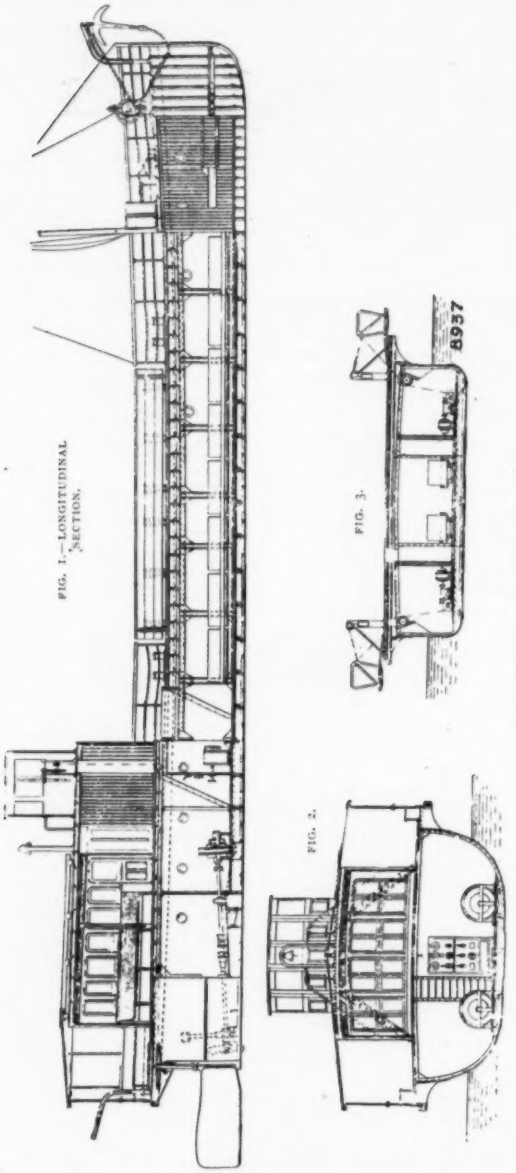

FIG. 1.—LONGITUDINAL SECTION.

FIG. 3.

FIG. 2.

ELECTRICALLY PROPELLED FERRY BOAT.

only high carbon tool steel, but low carbon steel also, is the Stassano furnace at the Bonner Fraserfabrik G.m. b.H., where tool steels having percentages of carbon varying from 1·3 to 7 per cent., with the addition of chromium, tungsten, nickel, &c., or low carbon steels having ·08 to ·2 per cent. carbon, are produced. The basis of the charge is wrought-iron scrap, costing £3 to £3 5s. per ton, though before the introduction of the electric furnace more expensive Swedish iron was employed, and 32 crucible furnaces, each containing six crucibles, holding 77 lbs. each, were used. The new furnace takes a charge of 1 ton, which is treated electrically for about 1½ hours; when poured, it leaves the furnace at a higher temperature, and therefore in a more fluid state than from the crucibles. In order to thoroughly mix the charge the furnace is slowly turned by a 5-h.p. electric motor driving through spur gear. As the electrodes are consumed they are fed forward by small hydraulic rams; the electrodes are supported by water-cooled cylinders.

The lining, which is fireclay, is renewed every twenty to twenty-five days; the re-lining takes about five days.

Electrical energy is purchased at a little over ½*d.* per unit (·55*d.*), and 900 units are consumed when treating 1 ton. The costs come out somewhat as follows:—

	£	s.	d.
Interest on capital ...		5	0
Current consumed ...	2	5	0
Cost of wrought iron scrap for charge ...	3	10	0
Fireclay lining		12	0
Electrodes		2	6
Cooling water			6
Wages (3 men)		10	0
Total cost per ton produced... ...	7	5	0

Electric Power Supply in Bulk.

Mr. C. H. Merz, in his recent paper to the Iron and Steel

Institute, told his audience that one result of electric power supply on the Tyneside had been to reduce the coal burned for power purposes by 50 per cent., with the result that a clearer atmosphere now prevailed. Hardly any coal is now burned for power purposes on the north bank of the Tyne, except in the electric power houses. A still further source of economy, and a notable one, is the starting of supplementary power stations using waste gases from coke ovens and blast furnaces, 13,650 h.p. being already obtained from this source. This in itself is a notable addition to the resources of a district which has for many years stood in the front rank as an industrial hive. The north-east coast produces more than half the shipping built in Great Britain; it produces about 36 per cent. of the pig iron, and mines nearly 40 per cent. of the ironstone raised in this country; 20 per cent. of all the country's coal is raised, and 40 per cent. of the entire make of coke comes from the district. This is more remarkable when the population is considered, as only 4·8 per cent. of the country's inhabitants live in the district.

Electric generating plant in connection with the Newcastle Electric Supply Co. totals up to over 101,000 h.p. The main station at Carville contains 56,000 electrical h.p. and has a greater output of electricity than any other electric supply station in Europe. Transmission cables radiate from the station in all directions; some trunk mains are 30 miles long.

The Carville station also supplies electrical energy to the electrified section of the North-Eastern Railway where, since electrification, the service has been doubled, and the mean speed increased by 20 per cent. Newcastle has the best electric railway service of any town of its size in the world. Notwithstanding the depression in trade further developments are contemplated. A 30 000 h.p. coal-fired station is under construction at Dunston-on-Tyne, and two smaller stations, one of 3,300 h.p. using coke oven gas, and another of 1,300 h.p. using exhaust steam, are also under construction, the latter on the Tees side.

A New Source of Illumination which has possibilities of usefulness is described in a recent issue of *The Electrical World* (New York) by Mr. G. A. Johnstone.

In order, however, that the properties of this new source of light shall be adequately understood it is necessary to point out that electrical engineers have for some time past used lightning arresters made of aluminium plates immersed in any suitable electrolyte. The property which is made use of is the fact that such a cell will permit only extremely small currents to pass through it up to a certain critical pressure, beyond which the amount of current which will pass through it is limited only by the resistance of the cell. This is strictly analogous to the safety valve on a steam boiler, which opens beyond a certain critical pressure. If, therefore, the line is operating under normal pressure (voltage), no current passes, but immediately the line is struck by lightning, or if a surge of pressure due to resonance takes place, the aluminium electrodes permit a great deal of current to pass, and will continue to do so until the pressure has fallen to the normal. The explanation of this action is that the aluminium electrodes become covered with a hydroxide film of aluminium which has a critical point beyond which it is incapable of resisting the flow of electricity, owing to the breakdown of the insulating properties of this film.

It has been observed that while the current is passing the plates or electrodes in the cell become more or less luminous, and this property has been investigated with results which seem to indicate possibilities of no small importance. With pure aluminium electrodes this illumination does not appear until comparatively high voltages are reached, and then small but very white sparks appear all over the surface of the electrode. One writer on the subject describes the appearance of the electrode as resembling the heavens on a clear starry night, due most probably to breakdowns in the coating of oxide and the formation of small arcs at these points. Alloys of aluminium were considered more likely to give more permanent sparking, as oxide would be more readily formed. This was found to be the case, and an alloy, frequently used for motor castings, composed of 90 per cent. aluminium and the remainder chiefly copper and tin, with small quantities of manganese, iron and zinc, and traces of silicon was tried. It was found that such electrodes immersed in a solution of common household borax could stand 250 volts if the pressure was gradually raised to that point. With this pressure and the alloy described the sparking observed with pure aluminium disappeared, and the surface of the electrode glowed until it resembled a piece of white-hot iron immersed in water. Lowering the pressure produced a light of an opal colour,

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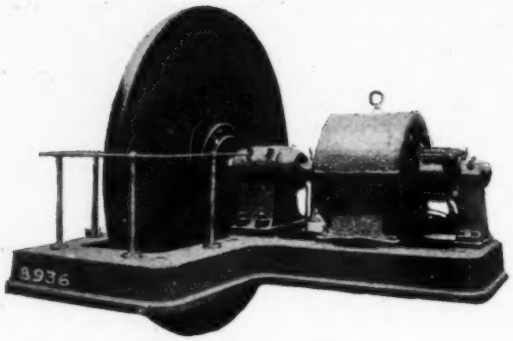


FIG. 4.—FLYWHEEL EQUALISER.

and the electrode resembled a tower or building closely studded with glow lamps, but with the lamps themselves obscured from view; indeed the effect appears to have resembled nothing so much as the buildings in the Franco-British Exhibition at night. As the pressure was raised beyond 200 volts small white shifting sparks appeared over the glowing surface, which became white, as already indicated. The glow resembles the corona which is frequently seen around an overhead wire carrying very high potential currents, though the explanation in this case is that there is a static discharge of electricity to the air through the very thin coating of aluminium oxide which forms on aluminium when exposed to the atmosphere. It appears that this new source of light is, even at this early stage, reasonably economical, for a cell containing two pencils of aluminium alloy immersed in an electrolyte contained in a test tube gives enough light to enable small print to be read at arms' length, and consumes only 8 to 10 watts.

Small Flywheel Storage Systems.

Our readers are already familiar with flywheel storage when applied to equalising the load due to winding engines and rolling mills. The development of the industrial applications of electricity has rendered necessary the introduction of such flywheel storage equipments for the purpose of equalising violent fluctuations of load, which may not be of sufficiently long duration to justify the installation of a storage battery with automatic booster, which costs a good deal to maintain on account of the rapid deterioration of the cells.

The Lancashire Dynamo and Motor Co. exhibited one of these small fly-wheel storage sets at Manchester exhibition, and have recently completed several for colliery and other purposes. One of these, shown in Fig 4, consists of a machine which is motored during the period of acceleration and acts as a generator during the period of retardation, and a plate flywheel weighing 5½ tons, running with a velocity of about 430 ft. per second. This flywheel is 8 ft. 9 in. diameter by 4in. thick, and runs at a speed varying from 950 revs down to 670 revs. per minute, the latter when the flywheel has given up the maximum permissible energy to the circuit. Forced oil circulation is employed.

The equipment operates very simply; the electrical machine, which performs alternatively the functions of motor and generator, is coupled to the mains just as an ordinary motor would be. It is started up through a starter, and when the normal light load speed, 950 revs., is reached the only energy it takes is that required to overcome windage of the moving parts, friction, and such magnetic and electric losses as take place in the motor.

If such a combination is to be of any use its voltage, when acting as a generator, must be largely independent of its speed. As the voltage of a generator is proportional to its speed, the E.M.F. would, under normal conditions, fall off rapidly, and it would fail to effect its purpose. To overcome this inherent difficulty the field magnet has three windings: (1) A shunt winding which, by maintaining a constant minimum field, prevents the motor running away. (2) A small series winding to compensate for the voltage loss in the armature. (3) A main series winding, carrying a varying fraction of the current in the circuit whose E.M.F. is to be regulated.

This latter winding has a diverter switch which cuts out more or less resistance across this field, so varying the proportion of the main current which passes through it. This automatic gear consists of two electromagnets operating one on each side of a toothed wheel, so that the wheel which is connected to the diverting resistance is rotated automatically in the direction that

is necessary. The machine will alter from motor to generator by the action of the windings alone, but the governor is essential to cause a larger part of the main current to pass through the series field so that the E.M.F. of the equaliser is maintained at the proper value.

The set in question will deliver 200 h.p. for three-quarters of a minute, and 100 h.p. for two minutes.

Railway Engineering.

New Locomotives for the Caledonian Railway Co.

The illustration on page 422 shows the latest type of locomotive which the Caledonian Railway are adding to their stock for the purpose of working goods trains, a number of which are presently being turned out from their St. Rollox workshops, built to the designs of Mr. J. F. McIntosh, the Company's locomotive engineer.

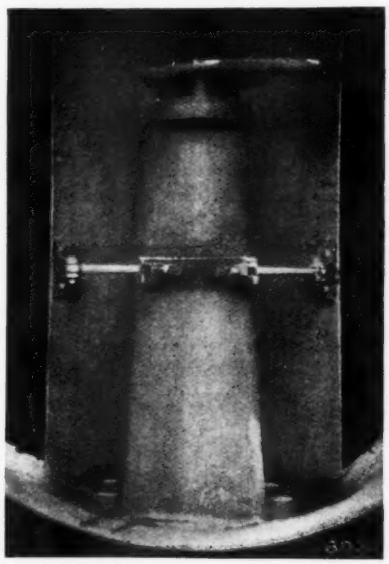
The engine is an 18½ in. by 26 in. by 5ft. six-coupled goods (652 class), and is of the 0-6-0 type, with inside cylinders driving on the middle axle.

The tubes are of mild steel, galvanised, 275 in number, and 1¾ in. external dia. The firebox shell is 6 ft. 5 in. long by 4 ft. 0⅛ in. wide at bottom, and the crown of the copper box is stayed with girder stays. The "Ramsbottom" safety valves are 3 in. dia. and adjusted to blow off at the working pressure of 160 lbs. per sq. in.

The cylinders, which are inside the frames with the slide valves between, are 18½ in. dia. by 26 in. stroke. The valve motion is of the Stephenson link type. The built crank axle has journals 8½ in. dia. by 7½ in. long, and the connecting rod bearing is 8½ in. dia. by 4 in. long. The leading and trailing axles have journals 8 in. dia. by 7½ in. long.

The engine is equipped with a steam brake, and has also an ejector and "through" vacuum brake pipe, thus permitting of the working of express goods trains.

A special feature in the construction is the introduction into the smoke-box of a novel form of spark arrester, which bids fair to at last solve the difficult spark problem by diminishing live-coal throwing while keeping the dead cinders in such a position in the smoke-box as to remain entirely clear of the bottom rows of boiler tubes. As will be seen from the illustrations, the apparatus consists of a V-plate interposed between the smoke-box tube-plate and the blast-pipe, and extending from the bottom of the smoke-box to a level just above the top row of tubes. It is fitted at its upper end with an angle-iron which projects very



SPARK ARRESTER FITTED TO GOODS ENGINE CALEDONIAN RAILWAY.

XUM

652 Class Railway Goods Engine. Caledonian Railway.

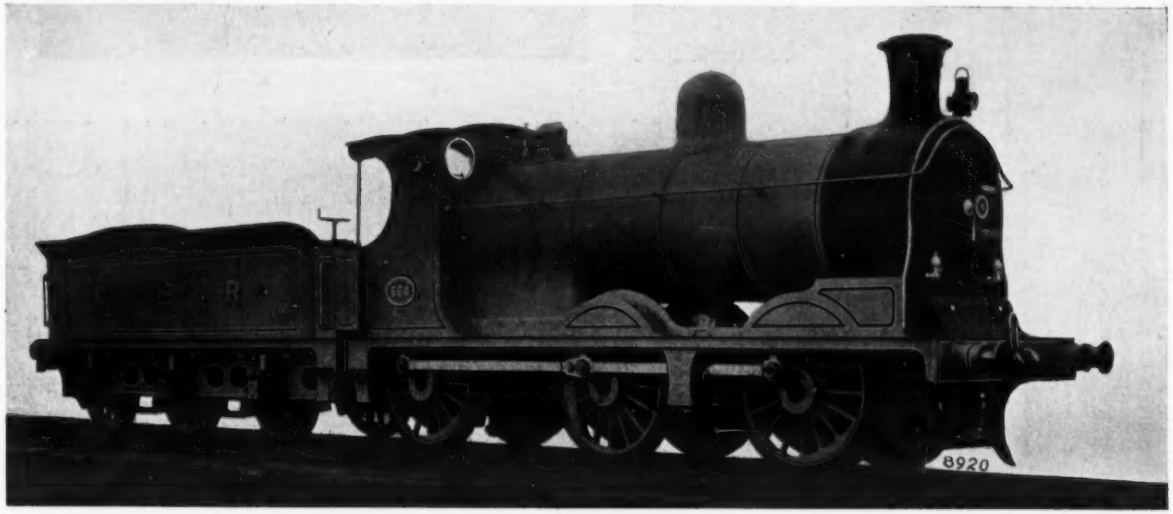
Principal Dimensions.

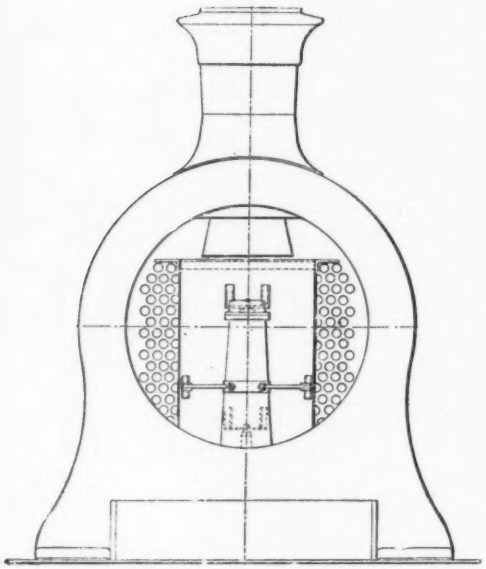
Engine.

Cylinders,	Diameter	1 ft. 6½ in.
	Stroke	2 ft. 2 in.
Wheels,	Diameter on tread (coupled)	5 ft. 0 in.
Boiler,	Height of centre from rail	7 ft. 9 in.
	Length of barrel	10 ft. 3½ in.
	Diameter of barrel	4 ft. 8¾ in.
	Thickness of barrel plates	$\frac{7}{16}$ in.
Firebox shell,	Length outside	6 ft. 5 in.
	Breadth at bottom	4 ft. 6½ in.
	Depth from centre at front	5 ft. 6 in.
	„ „ „ „ back	5 ft. 0 in.
	Thickness of covering plate	$\frac{1}{4}$ in.
Tubes,	Number	275
	External diameter	1¾ in.
	Distance between tube plates	10 ft. 7 in.
	Height of chimney above rail	12 ft. 11 in.
Heating surfaces,	Firebox	119 sq. ft
	Tubes	1,284 „
	Total	1,403 „
	Grate area	20·63 „
	Tractive force	17,800 lbs.
Working pressure		160 lbs. per sq. in.
Weight of engine in working order		45 tons 14 cwts.

Tender.

Capacity of tanks	3,000 gallons
Fuel space	4½ tons.
Diameter of wheels	4 ft. 0 in.
Weight of tender, full	37 tons 18 cwts
Weight of engine and tender in working order	83 tons 12 cwts
Length of engine and tender over buffers	51 ft. 1¾ in

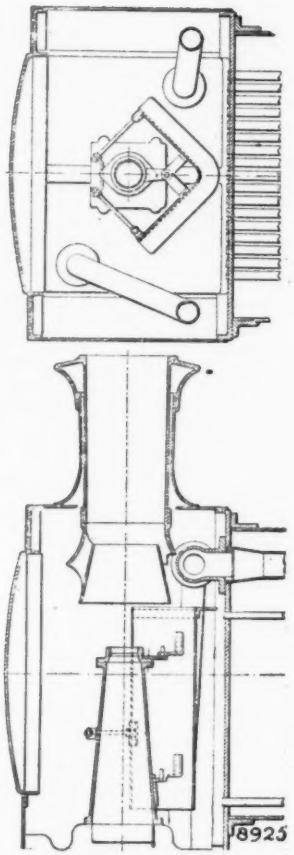




DETAILS OF SPARK ARRESTER. CALEDONIAN RAILWAY.

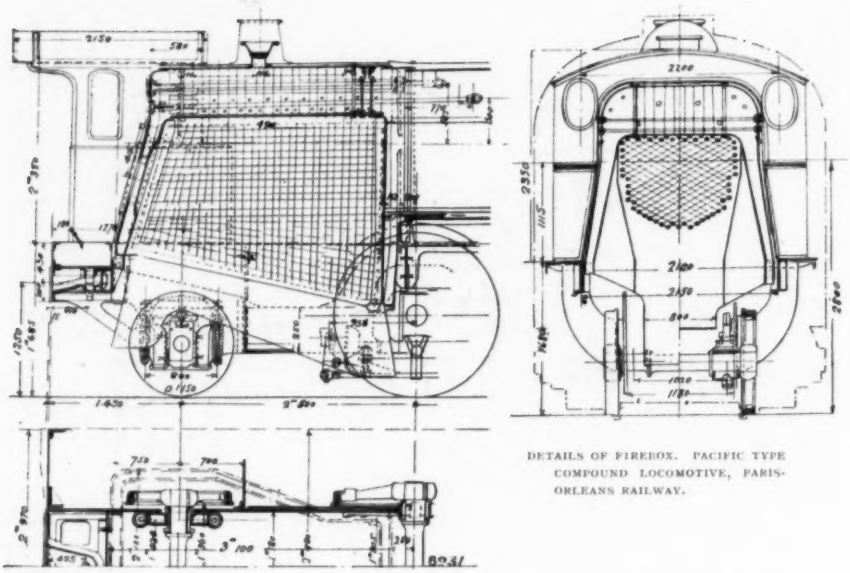
nearly to the tube-plate. This deflector plate is pivoted on brackets at the back of the blast-pipe, and is held in position by stays. Unlocking the latter allows this plate to be swung first round to one side and then to the other, so as to enable the tubes to be cleaned. The whole deflector can be easily lifted off its pivots and removed altogether if necessary.

In working, the ashes drawn through the tubes are deflected away from the strong current caused by the blast, and the cinders are piled up well in the fore part of the smoke-box, clear of the lower tubes. As the amount increases, instead of settling down to gradually block the lower tubes, the cinders roll back to within the V of the deflector, being thus kept away from the tubes. Live cinders are broken up on striking the plate, and whatever cinders are ejected are dead. This effective and simple arrester is the invention of Mr. McIntosh, and is the result of extended study and experiment in this particular direction; and so satisfactory has been its behaviour in actual working under severe and varying conditions that arrangements have been made for fitting it to all new Caledonian engines.



4-4-2 Type Compound Locomotive, Paris-Orleans Railway.

The vogue of the 4-4-2 or "Pacific" type locomotive is not diminishing, the latest company to adopt this design being the Paris-Orleans Company of France. Although compounded on the "De Glehn" system, one or two points of departure are to be noted as compared with other machines of this type at present in service in Europe. The most important divergence is in the construction of the fire-box, details of which are given in the accompanying illustrations. It



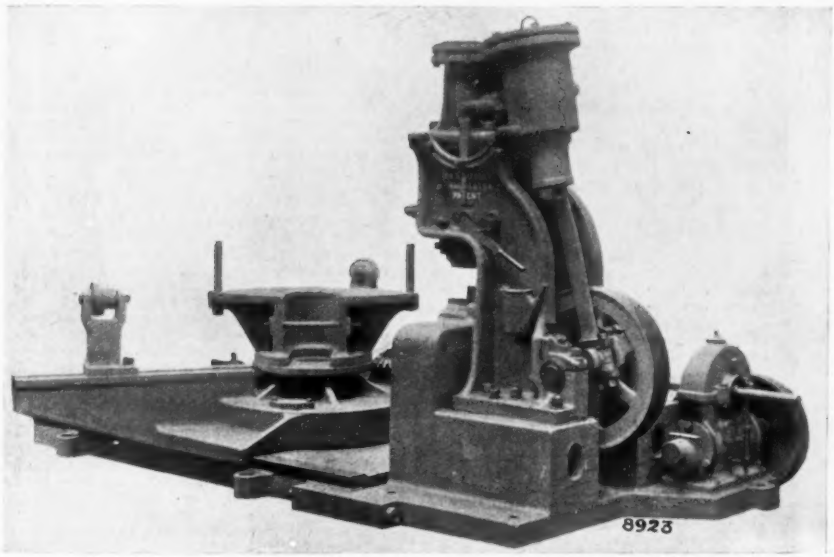
DETAILS OF FIREBOX. PACIFIC TYPE COMPOUND LOCOMOTIVE, PARIS-ORLEANS RAILWAY.

will be seen it is of the narrow-grate flat-crowned type in front, tapering out to a "Belpaire" design at the rear end. This permits the driving-wheels to be set back somewhat, and at the same time secures a deep space at the front end of the box, underneath the back end of the boiler. The next, and perhaps most noticeable, feature of the engine is the absence of the outside main steam-pipe, prominent in most French engines of the "De Glehn" type, the new arrangement permitting of a close setting of the pairs of high- and low-pressure cylinders. The former are set inside the frames, and drive the crank-axle of the leading coupled wheels, while the high-pressure pair are outside the frames, and connect with the middle pair. Steam distribution is by "Walschaert" gear and piston valves on all cylinders, the valves being placed on top. An intercepting valve is also fitted between the high-pressure and low-pressure cylinders. The following are the leading dimensions of this powerful engine:—

Cylinders, H.P., diameter	1 ft. 3·35 in.
,, H.P., stroke	2 ft. 1·59 in.
,, L.P., diameter	2 ft. 1·19 in.
,, L.P., stroke	2 ft. 1·59 in.
Admission, greatest H.P., 78·5 per cent; L.P., 80·5 per cent.	
,, least H.P., 11 per cent. L.P. 10 per cent.	
Wheels, diameter, bogie	3 ft. 0·2 in.
,, ,, coupled	5 ft. 10·8 in.
,, ,, trailing	3 ft. 7·3 in.
Wheel base, total	34 ft. 5·39 in.
,, bogie	7 ft. 6·2 in.
Bogie centre to first coupled axles	9 ft. 4·1 in.
Coupled	12 ft. 9·4 in.
Trailing coupled to rear axle ...	8 ft. 6·36 in.
Boiler, barrel mean diameter ...	6 ft. 6·1 in.
,, ,, length	18 ft. 10·3 in.
Fire-box, inside, length, top... ...	8 ft. 0·22 in.
,, ,, length, bottom ...	9 ft. 3·87 in.
,, ,, width	3 ft. 2·78 in.
,, ,, height at front from top	7 ft. 3 in.
,, ,, height at back from top	4 ft. 11·8 in.
Boiler tubes, number 261, outside diameter	$\frac{5}{16}$ in.
,, tubes, length between tube plates...	19 ft. 4·28 in.
,, heating surface, fire-box ...	165·4 sq. ft.
,, ,, ,, tubes ...	2603·6 sq. ft.
,, ,, ,, total ..	2769·0 sq. ft.
,, area of grate	45·9 sq. ft.
,, working pressure	227 lbs. per sq. in.
Weight, bogie in working order ...	22·26 tons.
,, adhesion ,, ,, ...	52·05 tons.
,, trailing ,, ,, ...	15·22 tons.
,, total ,, ,, ...	89·53 tons.
,, total, empty ,, ...	81·0 tons.

Pneumatic Hammer for Fixing Railway Tyres.

The accompanying illustration is that of an interesting machine recently introduced by Messrs. B. & S. Massey, Openshaw, for



PNEUMATIC HAMMER FOR FIXING RAILWAY TYRES.

fixing the retaining-rings in the groove of the tyres of railway carriage, wagon, and locomotive wheels.

The machine is pneumatically operated, air being supplied to the top and bottom of the hammer cylinder by means of a double-acting pump, which may be either belt or motor driven. The pump is driven by means of a forged steel crank and connecting rod, the driving pulley, which also constitutes a heavy fly-wheel, being mounted on the crankshaft and placed low down within the standard. The tup is a mild steel forging, and is guided in V slides, bolted to the standard; the piston and piston rod are forged in one solid piece.

The method of regulation provides for accurate control. As the lever is raised to its highest position the tup rises to the top of its stroke and remains there, leaving the anvil free. A slight downward movement allows the hammer to fall gently, and further movement causes blows to be struck which increase in severity as the lever is lowered. The tup can be held up off the work by means of a catch operated by a hand-lever, while the wheel is being placed in position on the table. Wheel tables in two sizes are supplied, one to take ordinary carriage and wagon wheels, and the other locomotive wheels. Each table is adjustable to suit the diameter of the wheels being dealt with, and its central part or drum is rotated by gearing, carrying the wheel with it. For small wheels this drum is rotated at constant speed, fast and loose pulleys being provided, both for the hammer crankshaft and for the rotating gear. The hammer for larger wheels has a countershaft driving both gears, and the rotating portion by means of a three-speed cone.

We are informed that the time taken to fix a tyre of a 3 ft. 6 in. wheel is 35 seconds, the whole operation, including fixing and removing from the machine, five minutes. This, as compared with hand labour, of course represents a great saving in time, and fewer men are required. The stroke of the hammer is 8 in., and the weight of the machine 3¼ tons, or in the case of the larger size for locomotive wheels, 5½ tons.

Glasgow Central Station Extension.

Although the alteration and extension of the Glasgow terminal station of the Caledonian Railway, involving some heavy

engineering work, was completed some twelve or more months ago, but little information has been available hitherto as to the details. At a meeting of the Institution of Civil Engineers held last month,* however, Mr. Donald A. Matheson, engineer-in-chief of the Caledonian Railway, who, in conjunction with Sir John Wolfe Barry, was responsible for the design and construction of the work, read an interesting paper describing the reconstruction and equipment, of which the following is an abstract:—

The Central Station in Glasgow is the principal station on the Caledonian Railway, and is situated in the heart of the city at or in the vicinity of the main thoroughfares and the river Clyde. It is constructed partly over the river, and over several streets, as well as over the Underground Railway, which runs longitudinally under Argyle Street. The original station was opened in 1871; but as the traffic has been almost constantly increasing, the accommodation has had to be enlarged twice within about twenty years.

Glasgow being the centre of a large industrial district, the traffic in the Central Station is very great. The number of passengers using the station increased by 5,156,465 per annum between 1890 and 1899, in which year the total number was 23,257,006. The traffic was then, however, seriously affected by the competition of the Glasgow Corporation tramways, so that by 1904 the number of passengers had fallen to 20,544,931, again rising, however, in 1906, to 21,874,520.

The average number of train movements in the station throughout the year exceeds 1,000 per day. The increase of parcels-traffic has been threefold since 1890. The suitability and capacity of the station was, therefore, quite outgrown, and increase of accommodation became a necessity. Glasgow Central Station is not, however, singular in this, as few, if any, of the original terminal stations of this country have stood the test of time in respect of traffic-working capacity.

The site of the Central Station is a difficult one, by reason of its position relatively to the river Clyde and to adjoining public streets, and, being in the centre of the city, the property which it was necessary to acquire was very costly. This affected the design, it being to some extent governed by the circumstances of environment. In the scheming it was realised that the measure of the accommodation to be provided was the great volume of intermittent traffic and the necessity of being able to deal with many thousand passengers per hour rather than with millions per annum. It was considered essential that there should be separation of the several kinds of traffic. For convenience in working, and with the view to the separation of particular traffics, it was decided to have the longest platforms on the extreme sides of the station, and, so far as practicable, use them for the departure and arrival of main-line trains respectively. The platforms for the shorter-distance and the suburban traffic were placed about the middle of the station. Fortunately, the majority of the trains for workmen run east and west by way of the low-level part of the Central Station, so that the scheme of extension of the Central Station was not influenced by the Cheap Trains Act of 1883, or the shadows of the revived Select Committee on Workmen's Trains, and the recently presented Bill in Parliament to amend the law relating to cheap trains, as under other circumstances it might very seriously have been.

The works were so designed that, in the event of future extension, there should be the minimum undoing of what had been done. The reconstruction had to be carried out so that there was never less accommodation available for the traffic than in the old station, and this was successfully accomplished without harming a single passenger or delaying a single train during the course of the work. The work was carried out partly by administration, and this course was justified by the result.

The station may be described as being a high-level station, the platforms being 24 ft. to 33 ft. above the level of some of the main streets which are crossed. The substructure is therefore a costly work of considerable magnitude. It consists of an extensive bridge over the river Clyde, and masonry arching and steelwork construction over and between the streets. These structures carry the station yard and the lines and platforms of the station proper. The space underneath the lines and platforms provides accommodation for a spacious parcels office and other purposes.

There are altogether thirteen platforms, but the width of the station at the concourse is so narrow that their ends had to be stopped in echelon. The concourse therefore lies obliquely to the lines and platforms instead of at right angles, as is more usual. The lengths of the main traffic-platforms range from 800 ft. to 900 ft., and of the less important from 450 ft. to 610 ft., while the widths vary between 22 and 30 ft.

As a criterion of the increased size of the station, it may be stated that the maximum width has been increased from 210 ft. to 360 ft.; the concourse has been increased in area from 550 sq. yds. to 3,000 sq. yds.; the platforms have been increased in aggregate length from 1,530 yds. to 2,910 yds., and in aggregate area from 6,250 sq. yds. to about 14,000 sq. yds.; the parcels-office has been increased in area from 500 sq. yds. to about 6,000 sq. yds.; and the roof of the train shed has been increased in area from 14,572 sq. yds. to about 35,278 sq. yds. Then, measured in single line, the permanent way in the station and its precincts has been increased from 1¾ mile to 5½ miles.

It was considered essential that the lines of the station-yard should be as numerous and as long as possible, and that there should be adequate auxiliary siding accommodation. The permanent way of the station-yard is so laid out that there is direct connection between any of the running lines and any of the platform lines, and the lay-out of the running and cross-connecting lines is such as to allow of the simultaneous movement of several trains in either direction. As the rails in the station are on a falling gradient towards the concourse, hydraulic buffer-stops have been provided at the end of each line of rails.

A feature of the accommodation is a special platform near the middle of the station, extending in length to about 1,000 ft. and of a width of 33 ft., on which there are two rows of columns for support of the roof. Two rows of columns are considered less obstructive than a single row, having regard to the streams of passengers and the luggage-barrow traffic. The purpose of this special platform is the working of two ordinary trains end on,

* November 10th.

that is, one in front of the other, access to the inner part being obtained by means of a crossover road between the adjacent lines near the middle of the platform. The expediency of this arrangement is doubtful, as the outer part of the platform is a long way from the concourse. The platforms are roofed in to about 86 per cent. of their length. This is a greater proportion than is usual, but the climatic conditions of Glasgow are exceptional. The roofing of the new part of the station, which is about 900 ft. long, is constructed of steel and glass, and the girders being elliptical in form there is pleasing vista in the length. The character of station roofing generally is discussed, and the roofing of Liverpool Street Station is set up as being ideal. The cab-rank is about 1,000 ft. long, and takes up a very important part of the area of the station, perhaps to the detriment of other accommodation. The method of dealing with passengers' luggage in this country necessitates such an arrangement in all British railway stations, whereas in Continental countries cabs are not brought into the main part of the station.

The concourse had to be of specially large area, and it is surrounded with the usual offices and appointments of a railway-station, among the latter being the train-information indicator. This indicator is a feature of the station, and is so placed that passengers can readily ascertain by personal observation all the information they require in regard to trains.

The ever increasing volume of the parcels-traffic necessitated the provision of extensive premises in the sub-structure of the station at the level of Hope Street directly underneath the passenger-platforms; there is direct communication between it and the platforms by means of a stairway and a series of hoists. This arrangement of the parcels-traffic accommodation has been found so advantageous as to suggest that the parcels-premises attached to all great terminal stations should be specially constructed either above or below relatively to rail-level, provided there is only a single hoist journey, that is a journey up or a journey down. The general accommodation and equipment is extensive and of the most modern character.

An extensive generating-plant is installed in the sub-structure of the station for the generation of electricity for lighting purposes, as well as for driving air-compressing appliances in connection with the working of the points and signals. Steam from the boilers of this installation is also used for the heating of carriages of departing trains and for the heating of the waiting rooms and other accommodation.

The signalling in connection with the old station was the ordinary manual system; but, after much consideration, it was decided to introduce a system of power-working in the extended station. Under the manual system, three signal-boxes were required, but, having regard to the large number of trains to be handled, particularly at the high-pressure period of the day, and the necessity there is for the swiftest possible operation, it was thought desirable to have one signal-box. This necessitated the elimination of the question of restrictive distance in the working of facing points, so that it was essential that there should be other operating agency than that of direct manual labour. It was ascertained that the capitalised value of the loss of efficiency of the station and the approach-lines which would have resulted from working by manual labour in three separate signal-boxes was more than enough to pay for power-working.

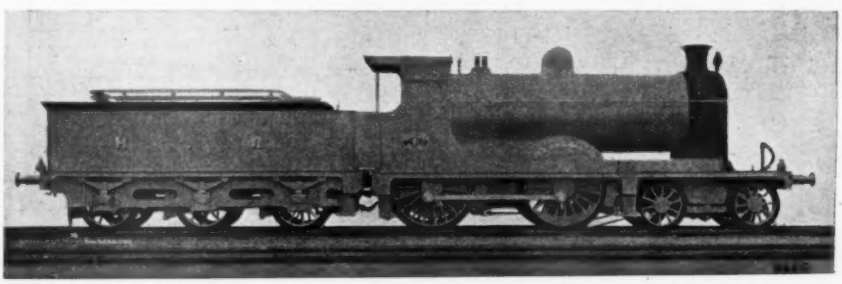
It was ultimately decided to adopt the Westinghouse electro-pneumatic system. There are 337 levers and 37 spaces in the interlocking frame, and the installation is said to be one of the largest there is.

The paper concludes with some reference to the principle in design. The author considers it doubtful if more than a very general principle exists, since so much depends on local circumstances.

He states that the measure of the sufficiency is not so much the area of the train-shed and the extent of the inside accommodation as the capability of the outside accommodation to be truly complementary; and he considers it may be laid down as an established principle in design that fitness and efficiency are governed by the character and extent of the outside accommodation, by which is meant the lines and lay-out of the station yard, the auxiliary sidings, and the approach lines, supplemented by an effective system of signalling.

The accommodation for the comfort and convenience of passengers, and the arrangements for service working inside the station, must also, of course, be carefully considered, particularly in respect of the relationship in plan.

At the busiest time of the day in the station there should, he urges, be a fixed ratio between the number of passengers and districts and the number of trains, the number of platforms, the number and facilities of the lines in the station-yard, the



NEW EXPRESS LOCOMOTIVE FOR THE HIGHLAND RAILWAY.

XUM

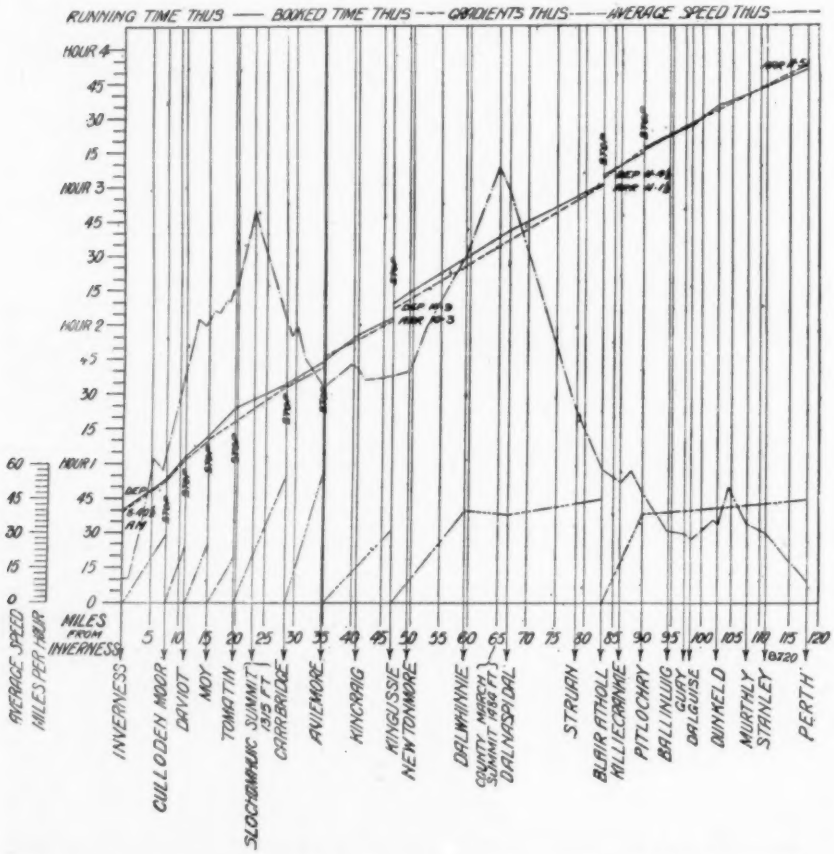
number of the approach-lines, as well as the extent of the auxiliary siding accommodation. Although the lines of the station-yard and the approach-lines in this catalogue appear in their order to be among the last of the factors of the problem, they are regarded as the first in importance, since they can be described as constituting the main artery of the station anatomy, while relatively the auxiliary siding accommodation is as vital as the heart.

With the essentials determined, the station must be schemed to meet the local and special requirements. The design of a terminal station in a great city will, however, in a measure always be governed by the circumstances of environment if, as there should be, there is due regard to engineering economics.

Everyday Work of Leading British Locomotives.

IV.—The Highland Railway.

Perhaps the hardest task allotted to any British locomotive is that of hauling express trains, involving loads frequently reaching 300 tons and more, up the long and severe gradients of the Highland railway. Some idea of these may be obtained from the accompanying chart of a run made by one of the principal trains of this line, on which



HIGHLAND RAILWAY. RUNNING OF THE 8.40 A.M. TRAIN, INVERNESS TO PERTH. ENGINE, "CAWDOR CASTLE," 4-6-0 TYPE; NUMBER OF VEHICLES, 4; NUMBER OF AXLES, 14; WEATHER, DAMP.

the gradients are plotted to a vertical scale, much distorted to enable their magnitude to be thoroughly realised. The length shown is the main line between Perth and Inverness; the railway, however, continues beyond the latter point to Kyle of Lochalsh in the west, and to Thurso and Wick in the north, involving altogether a length of nearly 300 miles, and traversing country the grandeur of which is unsurpassed in the British Isles. From Perth to Blair Atholl the gradients are not lengthy, but they involve climbs of 1 in 80, 93, 82, 90 and 85 for short distances. At the latter point commences the long climb of 16 miles across the Grampian mountains, the line ultimately reaching the summit at 1,484 ft., a short distance beyond Dalnaspidal Station, the highest point on any railway in the United Kingdom. Thence there is a rapid run down to Kingussie, with lengths including 1 in 80 and 95, followed by more regular stretches to Aviemore. Another steep climb succeeds, with lengths of 1 in 75, 60, and 70, to the Slochd Mhuic summit at 1,315 ft. above sea level, a sharp descent to Inverness succeeding with gradients of 1 in 60 and 70. The 35 miles from Aviemore was constructed as recently as 1898 to avoid the long detour *viâ* Torres, which until that date formed the only route to Inverness.

Long runs are not called for, and great speeds are obviously out of the question, on a line with such a conformation, but the locomotive work involved is none the less interesting or difficult, as the accompanying chart of a run made by the up 8.40 A.M. from Inverness shows. The longest non-stop run was between Kingussie and Blair Atholl (36 miles), on the upward grades of which the fine average speeds of 39 and 37½ m.p.h. were maintained (Kingussie to Dalwinnie and Dalwinnie to the Summit), followed by a careful run down to Blair Atholl at an average speed of 45 m.p.h. The engine was "Cawdor Castle," one of the class of 4-6-0 type engines designed by Mr. Peter Drummond, and until recently exclusively employed — unassisted in the case of the lighter loads—for working the express traffic. The dimensions of these engines, each bearing the name of a famous Highland Castle, are as follows: Outside cylinders, 19½ by 26 in.; coupled wheel, 5 ft. 9 in.; heating surface, 2,050 ft.; total weight of engine and tender, 100 tons.

A new series of 4-4-0 type engines constructed by the North British Locomotive Co., however, have been recently introduced, one of which is shown in the illustration on page 427. The leading dimensions are as follows: Diameter of cylinder, 18¼ in.; stroke of cylinders, 26 in.; steam pressure, 180 lbs.; diameter of coupled wheels, 6 ft.; diameter of bogie wheels. 6 ft. 6 in.; rigid wheel base, 9 ft.; total wheel base, 22 ft. 3 in.; boiler barrel (length), 10 ft. 6 in.; boiler barrel (diameter of smallest ring), 5 ft. ⅛ in.; heating surface, tubes, 1,516·2 sq. ft.; heating surface, firebox, 132 sq. ft.—total 1,648 2 sq. ft.; grate area, 20·3 sq. ft.; weight in working order, 49½ tons; water capacity of tender, 3,185 gals.; fuel capacity, 260 cub. ft.; weight loaded, 38¾ tons.

Although not so powerful as the "Castle" type, these engines have proved themselves equal to the requirements for which they were designed.

New Boat Train, L. B. & S. C. Railway.

The accompanying illustration is that of the new boat train recently introduced on the Newhaven service of the L. B. & S. C. R., and drawn by one of Mr. Earle Marsh's new tank engines. The train, which is unusually comfortable and well appointed, consists of eight bogie cars and a Pullman car, placed in the centre of the train. Of the eight ordinary vehicles, one is a 54-ft. second-class brake, four are 56-ft. lavatory composite carriages, first and second-class, and the remaining three comprise two 56-ft. composite first and second-class coaches and one 48-ft. brake.

NEW BOAT TRAIN FOR THE NEWHAVEN SERVICE, L. B. & S. C. R.

XUM

Iron, Steel and the Foundry.

Conducted by PERCY LONGMUIR, B.Met.

BLAST FURNACE PRACTICE.

The "Gayley" Dry Air Blast at the Warwick Blast Furnaces, Pottstown. —In a paper read before the American Institution of Mining Engineers Mr. E. B. Cook details experience with dessicated air blast. Gayley's results appealed especially to the management in that, for fifteen years, records had been kept at the works showing the amount of water entering the furnaces in the form of aqueous vapour, and careful observations had been made of its effect upon the working of the furnaces. It had been found impossible to make a satisfactory percentage of high silicon foundry iron in summer, even on high fuel, and for some years the endeavour had been made so to arrange the sales that during July and August only a small percentage of the iron produced would be required to carry more than 2 per cent. silicon. The larger furnace running on basic iron, year after year, produced in February a tonnage 20 per cent. higher than in August, on a much lower fuel consumption. At the same time the summer months were marked by "messes," tuyeres closed by slips and other irregularities, constituting serious inconveniences.

It was decided in the spring of 1906 to instal a plant of sufficient capacity to treat 70,000 cubic ft. of air per minnte. Assuming that 4·5 tons of air are required to make 1 ton of iron, then the daily production of 720 tons of iron calls for the treatment of 135 tons of air per hour. The plant employed is outlined as follows:—

Ammonia, liquefied by pressure is allowed to expand in pipes enclosing smaller pipes which carry brine, and this brine, thus cooled, is conducted through a refrigerating chamber in coils of pipe, over which the air of the blast passes and upon which it deposits its moisture before entering the blowing engine. The refrigerating part of the plant comprises five vertical single-acting compressors, each employing about 220 h.p. and having 175 tons refrigerating capacity. The object in having so many units is to guard against serious results from breakdowns; only in the summer months is the total capacity required. In winter one compressor will do the work for one furnace. An atmospheric condenser was installed above each compressor. The brine coolers are of double pipe with 3 in. outer pipes, in which ammonia expands, and 2 in. inner pipes, through which brine passes in an opposite direction. Through these coolers, and thence through the coils in the refrigerating chamber, brine is forced by one of two fly-wheel pumps. The cold brine enters the coils at the top. The refrigerating chamber contains 57 miles of 1¼ in. wrought iron pipe, divided into seven sections by partition walls and doors, so that one section may be washed free from frost without affecting other sections. Various troubles were encountered in the beginning, but these have been overcome and the dry air plant is earning the reputation of being the only "sure thing" about the p ant.

Details of the furnaces to which the dried blast was applied are given, and from these and the diagrams it is pretty obvious that the furnaces were not in good condition. Notwithstanding this, the application of dried blast showed good results. Experiences obtained after relining may be shown by taking the case of No. 1 furnace lighted on March 12th, 1908. Ten days after the first iron was made, dry blast was applied. Moisture was lowered from 4·5 grains on Monday, March 24th, to 1·5 grains on Tuesday. At the same time the revolutions of the engine were reduced 10 per cent. and the burden increased 5 per cent. The effect was immediate, for at 9 a.m., when dry blast was applied, silicon in the iron was 2 per cent.; at 5 p.m. it was 2·75 per cent. However, the same night the furnace stuck and continued so next day, the pressure reaching to 15 lbs., and at times stopping the engine. The application of cold blast did not

lower the pressure, and it was necessary on these occasions to relieve pressure entirely by throwing off the blast. The furnace would then settle, but the trouble recurred. After five days of unsatisfactory work it was concluded that the furnace was underburdened. The sudden application of dry blast had increased the heat in the hearth, and increased temperature not being met by increased work in the form of heavier burden, necessarily worked high up in the furnace, causing sticking at the top of the bosh. Therefore the burden was increased 15 per cent.; this resulted in the pressure holding constant, and the furnace has been settling regularly since. After these preliminaries in the fourth week of the blast the furnace made 1,311 tons of iron, using 2,090 lbs. of fuel per ton. The monthly records are as follows :—

1908.	Tons per week	Percentage of Foundry Iron.	Yield of Ore per cent.	Temperature of Blast. ° Fah.	Fuel per ton of Iron-pounds.
April ...	1,392	3	57·5	882	2,061
May ..	1,532	21	56·7	920	2,059
June ...	1,451	77	57·1	968	2,131
July ...	1,501	32	57·4	907	2,006

In discussing the results, a moderate estimate states the saving in fuel to be 400 lbs. per ton of iron; this is associated with an increased make of 350 tons per week, in spite of a lower blast temperature and a more refractory ore mixture. It is a remarkable fact that all furnaces using dry blast are showing about the same percentage of saving in coke and increase of product as compared with their previous work. However, dry blast is by no means a "cure all." Although it greatly increases the regularity of the furnace and enables it to be run closer, this very fact of lessening the margin of safety and running on a small slag volume and a siliceous slag makes the furnace more sensitive to changes of coke and variations in the ore mixture. The following explanation of results is offered: Of the heat value of coke entering the furnace only about one-fourth is available for heating the hearth, and in the ordinary furnace the hearth is the only place requiring greater heat. For years it was estimated that dry blast would only save 3 per cent. of coke; the fact was ignored that this 3 per cent. of total fuel would be saved to the hearth alone, and that this would amount to four times as much of the heat of the hearth; and as the hearth is the only weak place, the efficiency of the furnace would be increased 12 per cent. In this case dry blast decreases the duty of the hearth 12 per cent., and allows the resultant heat to be utilised upon increased quantities of iron and slag. Further increased burden, together with regularity of heat supplied to hearth, enables the slag volume to be decreased and the slag made more acid. This in turn saves fuel, and the increased product decreases the radiation per ton of iron, thus tending to further fuel economy.

The Relation of Density, Porosity, and Moisture to the Specific Volume of Ores.*—Mr. W. J. Mead gives a ready method for ascertaining the cubic content of a material as it lies in the ground, in order to estimate the amount in place, or tonnage represented by a given excavation, or to compare different grades of ore. The cubic content is a direct function of: (*a*) True specific gravity of the material, that is, the specific gravity unaffected by porosity or moisture; (*b*) porosity of the material, in terms of per cent. of volume occupied by pore space or voids; (*c*) percentage of moisture in the material, that is, the percentage loss in weight on drying at 110° C.

To facilitate the determination of the cubic content of ores the accompanying diagram has been devised expressing the relation between these three factors and the number of cubic feet per ton. Actual determinations in the ground are unsatisfactory, in that they do not show the individual effects of the three factors mentioned, especially moisture content, which may vary widely at different times and places. By the use of the diagram the three factors are considered separately, and their individual, relative, and net effects may be observed. The method was devised for the determination of cubic contents of Lake Superior iron ores, and results have been checked with a considerable number of empirical determinations by the mining companies.

The use of the diagram is shown by taking a concrete problem. Given an ore with a specific gravity of 4·5, porosity 30 per cent., and moisture 10 per cent.

Select a point on the upper edge of the diagram indicating the given specific gravity, 4·5; from there move downwards, as indicated by the dotted line, to the line representing the given porosity. From this point move upwards to the right, along the more steeply inclined lines, to the edge of the diagram. This point, 3·15, indicates the specific gravity as corrected for porosity. From this point move directly downward to the lower edge of the diagram

* *The Iron Trade Review*, by permission of the Director of the United States Geological Survey.

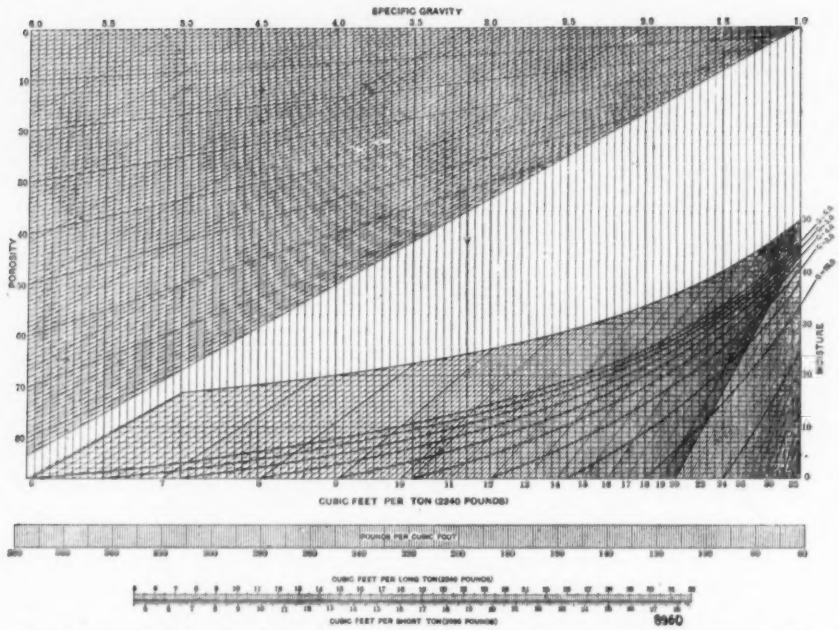


DIAGRAM ILLUSTRATING THE RELATION OF DENSITY, POROSITY AND MOISTURE TO THE SPECIFIC VOLUME OF ORES.

where the number of cubic feet per ton is indicated. This shows 11·4 cub. ft. per ton of dry material. The factor of moisture has not yet been considered. When moisture is present the material is heavier, and consequently the volume per ton is smaller. To introduce this factor of moisture, move directly upward from the last point, 11·4, to the horizontal line indicating the given percentage of moisture (10), and from this point down the inclined line to the lower edge of the diagram, where the number of cubic feet per long ton is found to be 10·2.

The diagram also contains a transformation table showing the relation between cubic feet per long ton, 2,240 lbs., and cubic feet per short ton, 2,000 lbs. For example, 10·2 cub. ft. per long ton is equivalent to 9·1 cub. ft. per short ton.

STEEL: ITS PROPERTIES AND TREATMENT.

Relative Corrosion of Steel and Wrought Iron Tubing.—Professor Howe and Mr. Stoughten, in a report in the Proceedings of the American Society for Testing Materials, examine the influence of corrosion in the case of steel and wrought iron. The latter is, in some cases, regarded as offering greater resistance to corrosion than steel offers, but there is no reason why steel should corrode worse than wrought iron. The most marked constant difference between them, the presence of cinder in iron and its absence from steel, creates no such reason. In that the particles of cinder themselves resist corrosion they protect the metal beneath. But their distribution is such that this protective effect may be equalled, or even outweighed, by their opposite effect of hastening corrosion by difference of potential. In summarising their tests the authors state that steel corrodes and pits less than wrought iron. This statement is founded on comparative tests made under a variety of conditions. Trials in locomotive and in stationary boiler tubing tended to show that there was no material difference between steel and iron. A twenty-six months test in the "Gayley" blast drying coil at the Isabella furnaces showed no difference between steel and iron, both of which had scaled uniformly. Five tests were more or less unfavourable to steel.

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Of these, two related not to modern steel but to that of 1897 or earlier, and one showed a condition of affairs wholly exceptional, whilst the evidence in another case is obscure. The whole of the tests show that tube steel has corroded less than wrought iron in seven distinct sets of tests by seven different sets of observers. In three other sets steel and iron behaved substantially alike. Eight of these ten sets were under conditions of service, and in six of them corrosion was pushed to destruction. The fact that steel has behaved as well and often better than wrought iron is good evidence that steel is not intrinsically materially more corrodible than wrought iron. Opposed to this evidence there is a very widespread and deep distrust of steel tubing, indeed a belief that it habitually pits deeply, and that wrought iron corrodes uniformly, a belief contradicted by the evidence. This distrust, so far as the authors know, is not based on any direct competitive tests between materials known to be good modern steel and wrought iron respectively.

FOUNDRY PRACTICE.

Production of Malleable Castings.—In the eighth article of this series* Dr. Moldenke discusses various methods of melting. The "Bessemer" converter process, whilst not used in America, has to a limited extent been used in some parts of Europe for the production of malleable cast iron. Small quantities of metals are blown at a time, and the process is practically that of the usual baby "Bessemer," except that blowing is stopped before the silicon becomes too low. The advantages of the process are doubtful, and there is nothing in it which cannot be done by the ordinary cupola process. It emanates from the mistaken idea that it is necessary to refine the metal to make good malleable castings. This is not the case, as the burning out of silicon, manganese, and perhaps a little carbon, in any of the processes for making malleable is that which is unavoidable in melting and raising the metal to the proper pouring temperature. In other words, if it were possible to simply melt without changing the composition whatever, the ideal melting condition would be obtained, as any strength gained by the reduction of the silicon and the carbon can be more easily and better obtained by charging steel scrap in the mixture.

The air furnace process is probably the most important in use to-day, and will likely continue so, as its advantages are numerous and the product excellent. The air furnace is cheaply built, and easily maintained and operated. Capacity may be as low as three tons, or as high as is consistent with getting the metal away and poured before it deteriorates through being held too long in the furnace. In melting iron for malleable castings, it should be remembered that as little refining as possible is desired. A short melt obtaining iron at the highest safe temperature for metal and furnace is the object to aim for. Refining whilst reducing the silicon and obtaining added heat by this means, always results in oxidation, the effect of which has become more noticeable since the charcoal irons were replaced by coke irons. It is, therefore, better to use coal or gas for fuel than silicon, besides it is less expensive. The additional strength obtained by refining, as formerly carried on, is best obtained by changes in the mixture.

In general, the efficiency of the air furnace should be 4 lbs. of iron to 1 lb. of coal, the latter to be of very good quality. The length of the heat will, in the case of a 10-ton charge, be about four hours from the end of charging to the beginning of tapping. A longer time than this represents bad practice, and, although the castings may not show surface defects, they will not give the requisite strength. Again, some furnaces will only melt 2 lbs. of iron to 1 lb. of coal, instead of double the amount. This represents a case of bad design or poor handling.

* *The Foundry.*

Leading Articles of the Month—Current Events—Technical Information from all Sources.

The Flow of Liquid Fuel through Carburettor Nozzles.*—In this paper the author continued certain investigations which were referred to in his paper read last year before the Society of Engineers. The action of a jet, as far as its properties of carburating air by means of liquid fuel are concerned, were considered, and its objects are set forth under the following heads:—1. To regulate the rate of flow of the fuel to suit the demands of the engine. 2. To disintegrate the fuel mechanically into the finest particles possible.

The regulation of the amount of heat required to supply the latent heat of evaporation and the temperatures which are reached under different conditions are given.

It was shown how a temperature of 10° C. would be reached if the theoretical proportions of air and petrol were combined and evaporated in $\frac{1}{20}$ second, the time taken for the mixture to flow from the carburettor to the engine.

The viscosity of fuels at different temperatures has been investigated by the author, who gave some tables, being results of experiments he has made by means of a special instrument and also with actual orifices of various sizes. The effect of the alteration of specific gravity, due to the rise of temperature, was also taken into account. The tables showed that the rate of flow of a spirit such as petrol is affected to a considerable extent by increasing its temperature. Comparative tables for benzol and petrol were given, which showed that with a small orifice, or with a low pressure head, the friction upon the fuel appears to be greater in the case of benzol than in the case of petrol, but as the size of the jet was increased the two fuels behaved almost alike, certainly within the limits of experimental accuracy, the benzol being slightly more viscous. For comparison of results the pressures at the orifice were reduced to inches of water-head in each case, and curves were plotted to demonstrate graphically the rates of flow with each fuel.

* R. W. A. Brewer, M.S.E., *Proc. Soc. Eng.*

The next matter considered was the relation between suction pressure and the air velocity, the paper being accompanied by curves which enable the ordinary user of liquid fuel to determine, by a simple calculation, the suction pressure at the carburettor jet in any specific case. Examples were worked out in the paper to demonstrate the application of this method, and the results were checked by actual experiment with a manometer. Cross-checking was done by utilising the curves and tables which have been determined for the rate of flow of liquids through the orifices used.

The tables make it apparent why extra air inlets are required in many types of carburettor, and show the effect of this extra air admission upon the system of carburation.

One of the most important features of the paper was the diagram of results of a large series of experiments upon the rate of flow of petrol through small orifices.

A series of carefully constructed orifices was obtained, graded and drilled to $\frac{1}{100}$ millimeter in diameter. These were in turn fitted to an instrument and the time noted for a sample quantity of fuel to pass through under various pressure heads. A table showed the rates of flow in gallons per hour under various conditions, which enables the diameter of the jet for any particular engine to be predetermined with some degree of accuracy. The author also pointed out that small aperture jets are somewhat erratic in their behaviour, which may account for some of the carburation disturbances in actual practice. An example of the rates of flow for a jet of 1·40 mms. diameter is 1·8 galls. per hour at 55° F., with a pressure head of 180 mms. of the fuel; but when the temperature of the fuel was raised to 70° F., the rate of flow increases to 2·14 galls. per hour. The pressure head corresponding to any given engine speed can be determined from the curve shown, and knowing the proportions of fuel to air required to give the best results, the size of jet can be read off from the curves. The paper showed how mean

values for ordinary road conditions can be obtained by a simple system of cross-checking.

The investigation was made with the object of clearly and graphically showing the action of a carburettor and the relations of the various dimensions, and their effect upon the resulting mixture of fuel and air. The author hoped that by means of simple reasoning the average user would be able to eliminate trial and error methods, and at the same time obtain a clearer understanding of the mechanical principles of a carburettor.

Different Methods of Impact Testing on Notched Bars.—So many methods of testing steel by impact have been suggested by engineers during the last few years that it has become a matter of importance to investigate the value of these tests as compared with the ordinary tensile tests which in the past it has been customary to rely upon largely, and also to compare the better-known methods of impact testing with each other to see which gives the most concordant results. At a recent meeting of the Institution of Mechanical Engineers* Mr. F. W. Harbord described a series of experiments undertaken by him with the object of (1) comparing the results obtained by different methods of impact testing; (2) seeing whether such tests detected any irregularity in steel not revealed by the ordinary tensile tests, and to what extent they were in agreement with the latter.

The methods of impact testing were too numerous to allow of all of them being experimented with, but broadly the methods may be divided into four or five classes as follows: (1) One notch in the centre of the bar; two supports; fracture effected by a series of blows of a falling weight (*Seaton and Jude*). (2) One notch in the centre of the bar; two supports; fracture effected by one blow of a falling weight (*Fremont*). (3) One notch not necessarily in the centre; one support; fracture effected by one blow on overhung portion from a falling pendulum or weight (*Izod*). (4) Two opposite notches not necessarily in the centre; one support; fracture effected by a series of blows of a falling weight on overhung portion (*Brinell*). (5) Same as (4), but with an arrangement for reversing the bar after every blow (*Kirkaldy*). Over 800 bars were prepared and tested, the detailed results of each being given in the paper. It appears that much irregularity was disclosed by the different methods of impact testing, but the author believes that this is not due to lack of uniformity in the material, but largely, at all events, results from the defects of the method of testing, and it is a serious question how far methods showing such variations should be relied upon by engineers to differentiate between the physical properties of different materials.

Taking the results as a whole, the Kirkaldy methods and Izod method gave results more in accordance with the tensile tests, and also showed less variations generally in the duplicate tests, but some of the results obtained by these methods varied so much that their value seems very doubtful.

The claim of the supporters of impact testing is that it indicates certain latent defects not shown under a static test, and therefore it is unfair to condemn impact results when they do not agree with the tensile tests. To some extent this is true, and if experiments had shown that duplicate tests might be relied upon to agree with each other within reasonable limits and the results were in general agreement with experience this contention would carry much weight; when, however, we find tensile tests on two steels show a difference of only about 4 tons with approximately the same elongation, and these results are confirmed by the analysis, and then impact tests of two such steels show by two methods the relative brittleness to be as 100 is to 16 and 100 to 21, while other methods give totally different results, one has very seriously to consider the value of these tests.

The Resistance of Materials to Impact.—The November meeting of the Institution of Mechanical Engineers was also occupied by a consideration of the paper of Dr. T. E. Stanton and Mr. L. Bairstow on the above subject. The general results of the experiments described in this paper prove, in the opinion of the authors, that for the detection of two important faults in materials, that is, brittleness and low elastic resistance, two distinct tests are necessary, according as a weakness in plastic resistance or in elastic resistance is to be revealed. The distinction between the tests to be applied will be appreciated from the consideration that for the former case an expenditure of energy is necessary which is approximately 300 times greater than that required for the latter.

The authors are of opinion that conclusive evidence has been shown that materials which are strong under alternating stresses are in general strong under those shocks which are likely to be put upon them in ordinary machine practice, and not weaker as seems to be commonly supposed.*

As regards the general methods of impact testing, the bending test on a notched bar seems to be the most searching and the easiest to be made. As the detection of brittleness in steel is of supreme importance, the one-blow method would be naturally the one most used, but for the study of the constructional value of a material its resistance to impact should be investigated, not at one point of the curve, but throughout a considerable range. To do this some form of impact tester should be used in which the energy of the blow can be varied,

* Nov. 20th, 1908.

* Seaton and Jude. *Proceedings Institute Mechanical Engineers*, 1904, p. 1135.

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and the specimen rotated mechanically. By a series of tests under varying strengths of blow valuable information can be obtained and the results correlated to those given by other methods.

Tests on Reinforced Concrete Beams.*—This important paper is in the main a record of more exact and detailed measurements of the actual deformation of concrete beams than have hitherto been made, and embodies a plea for a simpler treatment of the question from its theoretical side than has been usual in much recent work on the subject. All existing theories of the strength of reinforced concrete beams are based on the assumption that the deformation of the various layers of the beams follows the same law as that for an ideal homogeneous substance, *i.e.*, that it is proportional to the distance of the layers from the neutral surface. This law is not *absolutely* true for all steel sections. Exact extensometer measurements will indicate slight discrepancies, not of such a magnitude, however, as to mar the practical accuracy of calculations based on the law of linear strains. Concrete does not possess the same degree of homogeneity as steel, and the localisation of a large proportion of the internal tensile stress of the beam in the isolated steel rods must set up in the surrounding concrete conditions of stress not absolutely determinate, and in any case differing from those of an ideal beam in which the steel is supposed to be distributed through the entire width of beam. The extensometer measurements made at five layers of the beams tested show that the actual deformation curve may be (*a*) linear, as assumed in the theory; (*b*) concave towards the compression side; (*c*) concave towards the tension side. In no case can the exact form of the curves be known without actual testing. The concavity, when it appears, is quite distinct. The fundamental assumption of linear deformation is, therefore, inexact in many cases. Reference to the curves accompanying the paper shows that if a straight line be drawn joining the points representing the compression at the outer layer of the concrete and the extension at the reinforcement line, it would locate a layer of zero strain, *i.e.*, the neutral surface, in a position differing materially from that obtained by considering the five actual observations. This difference is a very appreciable fraction of the effective depth of the beam in many cases, and is quite comparable with, even if it does not exceed, the difference in the position of the neutral surface which results from comparative calculations based (*a*) on a constant modulus of elasticity of concrete; (*b*) on a variable modulus of elasticity of concrete. The justification of the introduction of the latter theory can therefore scarcely be tested by comparing its results with an experimental location of the neutral surface given by arbitrarily drawing a straight line between two points representing extreme tension and compression deformations.

The apparent exactness and the complexity of many recent formulæ suggest that they express closely the results of the most delicate physical experiments, rather than the results of tests of concrete beams. In the author's opinion these formulæ have been built up on an inadequate experimental basis, and it is his belief that a study of the results of careful measurements of the actual strains throughout a beam section, such as have been described, should form the starting point for our theoretical considerations. When this is done, the law of linear straining will be found to be only approximately true. The retention of the law of linear strain as the basis of any theory should then render unnecessary any elaborate modifications which produce changes comparable only with the degree of divergence of the actual from the assumed strains. Neither the conditions of laboratory test nor of practice can be specified to a degree of accuracy even approximating to that of some of the formulæ used, and the author trusts that a realisation of this fact may result in the general adoption of simpler formulæ, more appropriate to the actual conditions.

* E. Brown. *Proceedings Canadian Society Civil Engineers*, Oct. 15th, 1908.

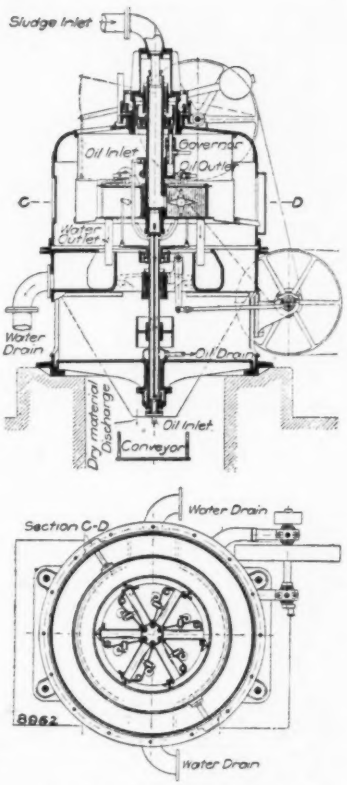
Drying Sewage Sludge in Centrifugal Machines.*—Many German cities have sedimentation basins connected with their sewerage systems, where the suspended matter is deposited, sometimes with the assistance of chemicals, before the sewage is discharged into the waterway which receives it. The sludge from these basins contains generally only 5 to 10 per cent. of suspended matter, of which 40 to 50 per cent. is inorganic and the remainder organic. It is estimated that on an average about 3½ to 4 cub. ft. of sludge are obtained from each 1,000 cub. ft. of sewage, and its disposal has caused much trouble. It cannot be dried on drained ground because the fatty matter in it soon clogs the pores of the soil, and the speedy evaporation of its water is impracticable for the same reason. By adding chemicals, peat and lignite, or by burying it in ditches the nuisance it causes can be overcome, but at great cost. It was learned some time ago that the material could be dried by centrifugal means, and one of the characteristic features of German sewage disposal work today is the favour shown toward this system of sludge treatment, which was described at length in the "Zeitschrift" of the Society of German Engineers, of September 5, by Mr. G. ter Meer. Mr. ter Meer has succeeded in designing a centrifugal dryer easily adjustable to the different conditions of the sludge. The machine is built for continuous service and works in two

* *Engineering Record*, N.Y.

alternating service periods. During the first period the sludge enters the machine and is dried by centrifugal force. After drying, the deposits are automatically removed from the machine during the second period. The revolving chamber receives the sludge through an intake pipe in its centre, and contains a number of radial compartments, which are provided with strainers; a common circular gate is provided both inside and outside these chambers.

The process of sludge-drying is performed as follows: The sludge is received by the different chambers from a basin above the machine through a pipe in the centre of the revolving chamber, the inner circular cut-off gate being open. By means of the centrifugal force all heavy parts of the sludge are thrown against the outer part of the compartments, and the water, which is lighter, is kept back. It runs through the strainers, and flows through a circular channel to the outlet. The space occupied by this water is now filled with new sludge from the central pipe, and after a comparatively short time the compartments are entirely filled with dry sludge. This point being reached, the inner gate is closed, and with it the sludge intake, and in this way the dry sludge is separated from the incoming material. Now the outer gate is opened, and the dried sludge is thrown out by means of centrifugal force. It is thrown against the wall of the hood, and by this action is crushed into small pieces, falling down on a conveyor. After closing the outer gate and opening the inner gate, the whole process is repeated. The dried material slides over the strainers and cleans them partially from sticky substances which obstruct the flow of the water. To be sure, however, that the strainer area is always kept clean, a mechanical cleaning device is provided. This is a star-shaped scraper, which, by means of a special device, is moved backwards and forwards. The two circular gates of the centrifugal device are moved by means of oil under pressure, which is carried through a drill hole in the shaft of the revolving chamber, as shown in one of the illustrations. Mounted on the stationary hood of the drying device is a revolving governing plate, which throttles the flow of the oil under pressure with the operating cylinders, and thereby the opening and closing of the circular gates.

The revolving chamber is entirely enclosed in a hood, and is operated by means of a belt. The shaft is supported by three bearings. The hood is made of wrought iron at those places where the dried material is thrown against it. The main bearing of the shaft is so arranged that the weight of the revolving parts is taken up by oil under pressure, which enters at the centre of the step-bearing. Since the high pressure generated by the centrifugal force throws small water particles from the chamber, even when the gates are made as tight as possible, it was necessary to supply some preventive of this, for otherwise these particles



CENTRIFUGAL MACHINE FOR SLUDGE.

would collect on the wall of the casing and become mixed with the sludge again, thus considerably reducing the efficiency of the machine. Around the chamber, therefore, there is a concentric ring which takes up the water; it is automatically removed shortly before the dried material is thrown out, and after that replaced in its original position in the same way.

The material taken from the machine is dried so that it can be taken up easily by a conveyor.

The dried sludge may be used as a fertiliser, or burned in a refuse destructor. Tests made in Frankfort with the material in a gas-producer gave 20 cub. m. gas from 100 kg. dried sludge; the gas had a thermal value of 3,800 to 4,250 calories per cubic metre. Centrifugal sludge-drying plants are now in operation at Harburg and Hanover, and one is being installed at Frankfort.

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Proposed Goods Subway for New York City.—An interesting proposal has recently been put forward for improving the facilities for handling the goods traffic of the city and port of New York, consisting, briefly, in the construction of a goods subway under the streets of Manhattan, bordering the North River. The type of car proposed would have sufficient capacity to accommodate the largest package of goods, and would run in a subway 8 ft. 6 in. in height and width for each single track. The subways would connect with the New York Central lines, and by a four-tube tunnel under the North River with the railways terminating on the New Jersey side. Branches from the subways would lead to warehouses and piers along the river front. It is estimated that the subway cars would be large enough to handle at least 90 per cent. of all the commerce of lower Manhattan, with but one change of bulk, and that made at points remote from the congested portions of the city. It is proposed to use electricity as a motive power, and to so construct the cars that they can be easily handled on steep inclines, sharp curves, and on lifts. The plan differs from that of the freight subway in Chicago, in that its proposed location is immediately beneath the streets instead of some 40 ft. below road level.

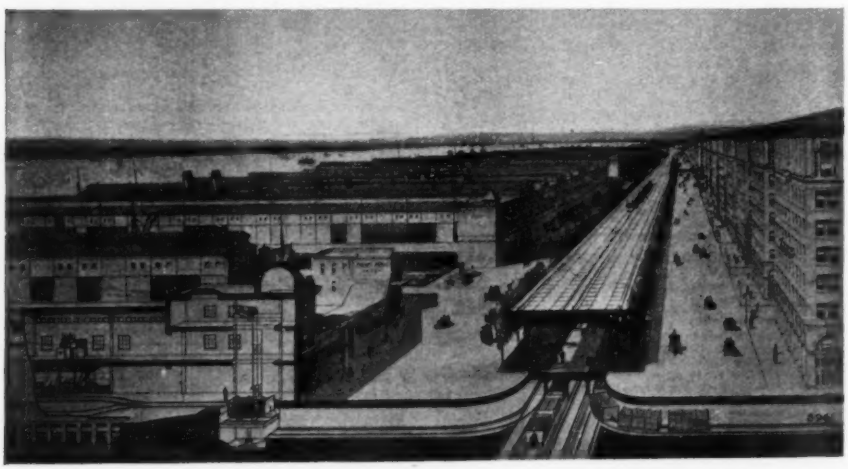
Perhaps the most important feature of the scheme is the provision that the main lines shall not be blocked by point movements. Crossings are eliminated at diverging points, and the principle is adhered to that traffic movement shall always be in one direction, and reverse movements are not allowed. The cars are to be operated by electricity on the multiple unit system, so that a train can be split up and moved in sections for distribution without delays involved by shunting with a locomotive at the head.

Some Problems of the Motor Car.*—Ever since 1903 marvellous progress has been made, and most of the difficulties of the engine, clutch, change-gear and transmission have been met with such success that the flexible and smooth-running car of to-day appears to many so desirable as to present no further problems for the energy of the automobile engineer.

To others the present cars appear to embody only partial solutions of many problems. The clutch, for example, even in its best form, is a contrivance which should be abhorrent to the soul of the mechanic. It is a practicable mechanism, no doubt, which causes less damage to transmission gear than would be expected, but this is largely due to the excellence of the material of the modern car and the intelligence of most car drivers.

It has long seemed to me possible to design a pneumatic clutch connecting the engine and the driven shaft, so that no violent shocks could reach the transmitting mechanism. Such a clutch would consist essentially of two or more cylinders mounted on the end of the driven

* Abstract of the Presidential address by Dugald Clerk, M.Inst.C.E., before the Incorporated Institution of Automobile Engineers.



VIEW OF PROPOSED SUBWAY SYSTEM FOR FREIGHT DISTRIBUTION IN SMALL CARS ON WEST STREET, NEW YORK CITY, AND ELEVATED PASSENGER RAILWAY ABOVE.

shaft and rotating with it, and a crank on the end of the engine-shaft connected to two or more pistons working in the rotating cylinders.

Change-speed gear also seems to be a very inferior mechanical device for varying the effort made possible to the road wheel. This has been much felt by motor car designers, and perhaps more mechanical ingenuity has been expended by them on various methods of getting a wide range of intensity of wheel effort without changing gear than on any other part of car mechanism. The system of gear-changing by sliding toothed wheels, notwithstanding its apparent mechanical crudity, has proved to be the principal survivor in the struggle, and its efficiency of action has certainly been greatly improved. If we must have gear changed at all, the quiet and easy gear-change of to-day leaves little to be desired.

Other efforts have been directed to the improvement of the petrol engine itself, with the object of dispensing with change of gear ratio as much as possible, and accordingly this mode of development has produced the moderately high-power car of to day, with its direct drive, live axle, and highly flexible engine. Success in this direction requires an engine capable of giving the maximum torque required by the road wheels on steep hills while geared on the direct drive, and, of course, it involves a powerful engine which runs at a very light load at customary speed on the level. For the greater part of its running, the engine will be only developing about one-fourth of its maximum power in order that the full power may be available for hill-climbing, without requiring change of gear. The necesssity of carrying about this heavy and powerful engine, for but a small use of its full power, has been justly recognised as a disadvantage, and many methods have been devised for temporarily increasing the driving torque to be obtained from a small engine. Such methods include: The petrol-electric car, in which an accumulator supplies an electric motor, giving power to the driving shaft when the resistance to motion increases sufficiently, and the electric motor acts as a dynamo, and charges the accumulator when the engine is running under conditions of lighter load, and proposed air-reservoir cars, having pumps to fill up the reservoir, which, in turn, assist the engine when required.

Other inventors seek to increase torque by providing air pumps supplying the air and petrol charge to the engine under a pressure above that of the atmosphere. Daimler was the first to propose this, and he has been followed by many, including Mr. Dawson and Mr. O'Gorman. They, however, require a heavier engine to withstand the higher maximum pressure of explosion; and although the cylinder dimensions remain small in reality, the weight of the engine, to provide the same margin of safety, requires to be increased, as much as it would be by using larger cylinders.

So far attempts to increase the torque of a small power light engine have failed; it is very desirable, however, to persevere, as it appears probable that a much better type of car is possible, and many advantages to the public would follow success.

I have made experiments with super-compression devices of different kinds, which convince me that it is possible to arrange for the increase of the mean pressure upon the piston at the slower speeds of rotation by about 50 per cent. without increase of maximum explosion pressure. To do this it is necessary not only to increase the charge supply pressure as proposed by Daimler, but also to increase the volume of the compression space. By the simultaneous increase of charge pressure and compression space volume, torque is greatly increased, although, of course, expansion is diminished, and the theoretical economy is somewhat reduced. My experiments have been made on relatively large gas engines, two engines of 22 in. cylinder diameter, one of 10 in. diameter, and another of 7 in. diameter, but the reasoning applies to small petrol engine cylinders. Such an increase of mean pressure as I have suggested would enable cars of moderate power to dispense almost entirely with change of speed gear. My present car, for example, would be able to climb all the hills in my district without changing from the direct drive on the third speed.

If the pumping arrangements could be operated by a small separate petrol motor, nicely balanced and always running, the main engine could be arranged to act as a compressed air engine only when in traffic or on hills at slow speed. The added engine and pumps increase the complication, but it seems to me possible to reduce total weight by the reduction of main engine dimensions and the simplification of gear-box arrangement. A car which could be stopped and started in traffic without the need of the clutch, and could stop on a steep hill in the same way, with the certainty of starting smoothly, would combine the advantages of both steam and petrol engines.

Recent improvements in the petrol engine, such as very large inlet and exhaust valves and very light pistons and moving connections, have made it possible to greatly increase the total power to be obtained from cylinders of given dimensions by permitting of longer strokes and higher speeds of rotation, while keeping up the weight of charge dealt with per stroke.

The famous 4-in. race has shown it to be possible to get about 60 i.h.p. from a 4-cylinder engine having 4-in. diameter cylinders, at a speed of about 2,000 r.p.m. The interesting new Daimler-Knight engine, in which lift-valves are replaced by sliding piston-ring sleeves, admits a larger charge at high speeds than is usual with ordinary valves, and so secures greater power for given cylinder dimension.

I look forward with much interest to the coming year's experience with this fascinating form of petrol engine.

All these improvements increase the power of control, but not the flexibility.

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WORK OF 1 H.-P. MINUTE MEASURED IN CUBIC INCHES OF METAL REMOVED; FEED INCREASING.

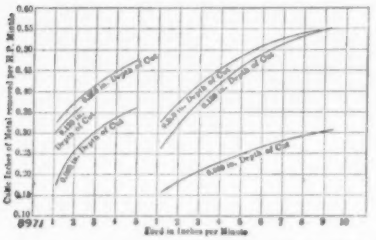
Cubic Inches of Metal removed per H.P. Minute
0.250 in. Depth of Cut
0.125 in. Depth of Cut
0.062 in. Depth of Cut
0.250 in. Depth of Cut
0.125 in. Depth of Cut
0.062 in. Depth of Cut
Feed in Inches per Minute
8971

FIG. 1.—CUTTING SPEED 12 FEET PER MINUTE.

FIG. 2.—CUTTING SPEED 32 FEET PER MINUTE.

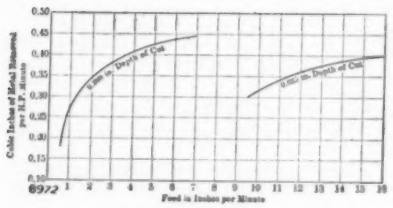

FIG. 3.—CUTTING SPEED 45 FEET PER MINUTE.

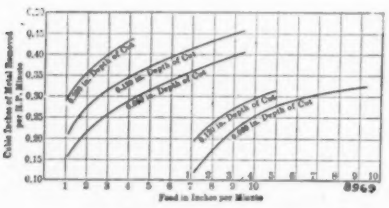
Cubic Inches of Metal Removed per H.P. Minute
0.250 in. Depth of Cut
0.125 in. Depth of Cut
0.062 in. Depth of Cut
0.250 in. Depth of Cut
0.125 in. Depth of Cut
Feed in Inches per Minute
8969

FIG. 4.—CUTTING SPEED 67 FEET PER MINUTE.

FIG. 5.—CUTTING SPEED 150 FEET PER MINUTE.

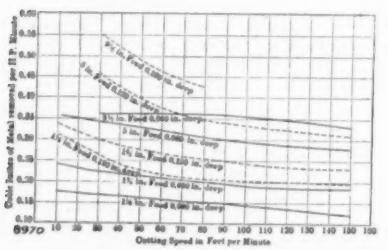

FIG. 6.

While even better results may be desired on the two points—clutch connection and true flexibility—another important matter requires persevering attention. I refer to the exhaust products discharged into the air of our streets; the rapidly increasing use of private and public motor cars in cities raises the study of the carburettor to a position of national importance.

It has been clearly proved that the product discharged from an engine when the mixture of petrol and air is properly proportioned is innocuous in its chemical nature; combustion is almost complete; but when proportion is incorrect, and vaporising action imperfect, the products are noxious. Carburettors at present proportion correctly at two or at most three points of load and speed; at intermediate points some deviation occurs.

The problem of proportioning accurately and automatically for all speeds and loads is one of great difficulty, and existing devices provide an imperfect solution. It cannot be too firmly borne in mind that a mixtnre of constant composition is required at low and high speeds and low and high loads.

Methods of carburettor control which depend entirely on engine speed cannot produce accurate results, because the engine may run at the same speed under quite different conditions of throttle opening. What is really required is some method of controlling depending solely on the charge volume which passes the jet.

A practically successful method capable of meeting all the conditions has still to be designed.

Tests of Milling Machines and Cutters.[*] — When the Cincinatti Milling Machine Co. entrusted me with the design of their horizontal and vertical power millers, the main points to be settled by me were:—

(*a*) How much metal shall a machine of given size be capable of removing? (*b*) How much power is required for this work on existing machines? (*c*) Is it possible to improve on the efficiency of present machines and still produce a commercially successful machine? (*d*) How much power is required for the feed? (*e*) What is the efficiency of the feed mechanism?

To determine the first point, tests were made on various makes of machines. The metal to be cut was in all cases, both in these tests and in those to be described later, steel of the following specifications:

Combined carbon	·16 per cent.
Silicon	·008 per cent.
Manganese	·51 per cent.
Phosphorus	·086 per cent.
Sulphur	·041 per cent.
Tensile strength per square inch ...	52,378 lb.
Limit of elasticity	30,313.
Elongation per cent. of length ...	50 per cent.
Per cent. reduction of area ...	54 per cent.

The test blocks used were 18 in. long, 5½ in. wide and 5½ in. thick. The ends were milled

[*] A. L. DeLeeuw. *Proceedings American Society Mechanical Engineers*, December, 1908.

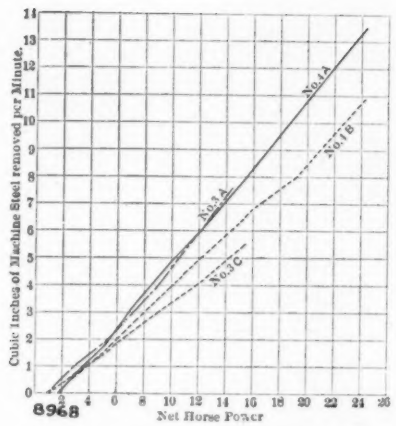

FIG. 7.—CUTTING EFFICIENCY CURVES.

in to provide means for holding the block on the table of the milling machine. In all tests a spiral cutter with nicked teeth was used, 3½ in. in diameter, 6 in. face, and for a 1¼-in. arbor. All tests were made by driving the machine by an electric motor, belted to the machine. The power consumed was ascertained by reading of ammeter and voltmeter, and the amount of metal removed by measuring width and depth of cut and the amount of feed per minute. The amount of feed, as indicated on the index plate of a milling machine, is generally an approximation, near enough for everyday work but not for a test. The actual amount of feed was therefore computed from the gearing.

Power Required to Remove Metal.—A series of tests was made with a depth of cut of $\frac{1}{10}$ in., $\frac{1}{8}$ in., $\frac{3}{16}$ in., $\frac{1}{4}$ in. and $\frac{3}{8}$ in. For each depth of cut a number of different feeds were used. In all cases the even feeds were used, starting with the second (next to the lowest) and increasing thus: 2nd, 4th, 6th, 8th, 10th, &c., up to the highest feed. In plotting the curves, the test readings were first corrected; the power readings by means of efficiency chart of the motor; the amount of metal for loss of speed of the machine. The amount of power required to remove a given amount of metal varied with the speed, depth of cut and feed per minute, and seems to have a tendency to the minimum when the section of the chip removed per tooth approaches most nearly a perfect square. Figs. 1, 2, 3, 4, 5, and 6 show curves giving relation between power required and metal removed under different conditions of speed, feed and depth and cut. They are partly derived from the tests described, and partly from tests made for the special purpose of ascertaining these relations.

All machines were worked up to a limit far beyond what they would be required to do in daily operation. It goes to show, however, how utterly foolish it would be to furnish these machines with larger pulleys or wide belts for the purpose of giving them more capacity, as they can do much more work, even with their present pulleys and belts, than some of the other parts will permit. Taking the product of belt width and speed, and calling this 100 for the 4-A machine, then the corresponding product for B No. 4 is 144. Calling this same product 100 again for No. 3-A, the corresponding product for the C No. 3 machine is 154. This shows clearly again the small value to the buyer of the size of driving pulley or belt power.

Fig. 7 shows the curves obtained, the abscissae being the number of horse-power net and the ordinates the numbers of cubic inches of metal removed per minute.

In order to determine the efficiency of the feed mechanism, the amount of power used was measured, as well as the amount of work done by the table. As the amount of power required varied widely, and it would be impossible therefore to obtain an efficiency chart for some small motor, covering the entire range of powers used, the idea of using an individual motor for the feed alone was abandoned. Instead the same motor was used as had been used for other tests. The efficiency of this motor was not known below ¼ load. It was then necessary to provide an artificial and constant load for the motor. For this purpose the square box shown in Fig. 8 was mounted on the spindle arbor. It had a paddle inside and a number of obstructions which made the required resistance for the water in the box. By increasing the amount of the water in the box, and by giving the paddle various speeds, any load could be produced within the range of apparatus, and the load was constant. The dead load was adjusted until it came within the efficiency curve of the motor. The apparatus used for measuring the work done by the table consisted of a dynamometer, graduated and calibrated up to 8,000 lbs. One end of this dynamometer was attached to the table of the milling machine. A chain at the other end of the instrument was wrapped round a drum which was mounted on a brake of the "Weston" type. An arm mounted on the brake casing and visible in the drawing had at one time been used to determine the efficiency of the driving mechanism, but was not used in this experiment, except to form an abutment for the brake. The brake itself was used only as a safety device, being set at sufficient pressure for the test, but not enough to wreck the machine. All even feeds were taken, beginning with the second lowest and going up to the highest. For each feed the following pressures were selected: 1,000, 2,000, 3,000, 4,500 and 6,000 lbs. The entire series was repeated once if nothing happened to spoil the test.

Before taking a series of readings, the feed mechanism was disconnected to get the reading of the dead load. Another reading of the dead load was taken after each series of readings

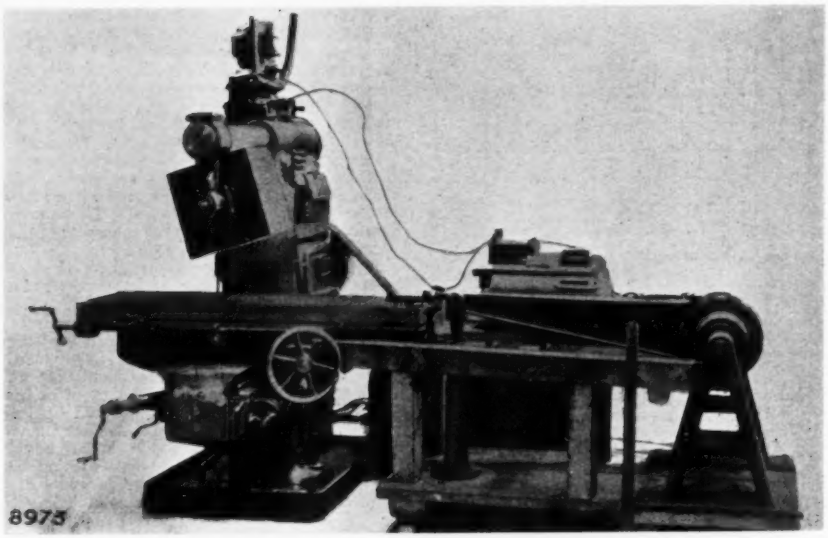

FIG. 8.—APPARATUS FOR TESTING FEED EFFICIENCY OF MILLING MACHINE.

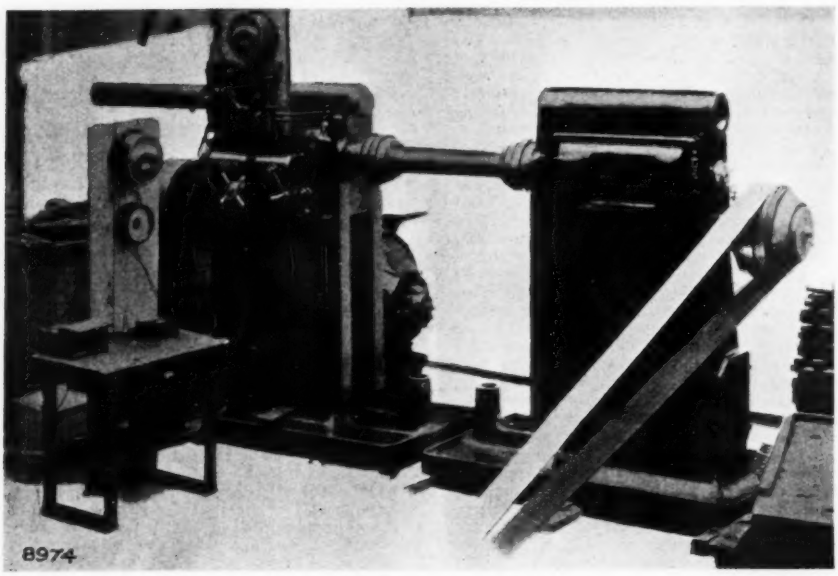

FIG. 10.—APPARATUS FOR TESTING EFFICIENCY OF MILLING MACHINE DRIVES.

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was completed: that is, after all the different pressures had been used for one single feed.

Fig. 9 shows the curves of average values plotted from these readings, in which each ordinate is the average of the ordinates corresponding to a certain amount of feed. The result of these tests justify again the precaution taken to obtain an efficient feed mechanism in the new milling machines. These precautions consisted in avoiding idle running gears, high-gear velocity, combined tortional and bending stresses in shafts, ill-supported and floating bearings, and above all, in the use of quick pitch screws.

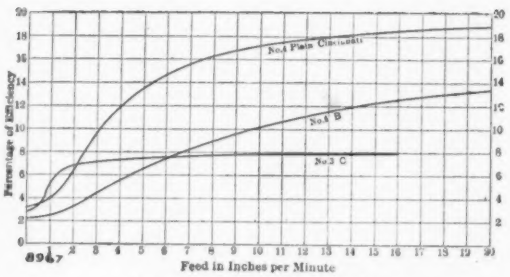

FIG. 9.—FEED EFFICIENCY CURVES.

Tests on Efficiency of Driving Mechanism.—The third series of tests relates to the efficiency of milling machines as power transmitting devices, that is, the ratio of input and output of power. The tests were carried on with the apparatus shown in Fig. 10. This consisted of two machines of the same type and size, namely, "Cincinatti No. 4" high-power miller, placed opposite each other and connected by a stout shaft. The feed works were removed, as was also knee, saddle and table. A flange was screwed to the nose of each spindle, each flange was provided with a tongue engaging the groove in the similar flange opposing it, and keyed to the connecting shaft. One of the machines was driven by a motor while the other drove a generator. The current thus generated was dissipated in a water rheostat, by means of which the amount of current could be closely regulated.

The speed controlling levers of both machines were always in corresponding positions—that is, both were set for the same speed, so that at whatever speed the spindle was running both driving pulleys were always running at the same speed, and that is the speed at which they are supposed to run under working conditions. Different sets of readings were taken. In one set the current consumed was kept at as near 125 amperes as possible. In another set this amount was 100 amperes; in still another, 80, and in the fourth, 70. Each set of tests was carried out over a number of speeds, namely, the lowest, third, fifth, &c., up to the highest but one. After correcting the motor reading for motor efficiency and generator reading for generator efficiency, the quotient of the corrected readings gives the product of the efficiencies of the two machines.

Considering the efficiency of each machine as practically constant, the efficiency equals the square root out of output divided by input. The curves presented in Fig. 11 are based on this assumption. It will be seen that the efficiency of the machine varies from 67 up to 79·7.

Efficiency of Cutters of Different Type.—The milling machine is not essentially less efficient as a power transmitter than any other machine tool, but the amount of metal removed per h.p. per minute is low: much lower, in fact, than for the lathe or planer. Were it not for other properties, the milling machine could not compete with either of these two machines. It is fortunate for the milling machine that the question of power consumption is of minor importance in considering the purchase of machine tools. Still, it cannot be denied that the milling machine would be esteemed higher if its power consumption could be brought down to the level of the lathe. It is obvious that this cannot be done by increasing the efficiency of the mechanism, as the margin is not large enough to allow of any material improvement. Any substantial increase of efficiency must therefore be found in improvements of the cutting tool.

With this consideration in mind, some tests were made as to the power required to remove a given amount of metal with different styles of cutters, which bring out in a startling way the amount of improvement that may be made in this direction.

Cuts made with a spiral cutter with nicked teeth showed a best efficiency of 0·48 cub. in. of metal per net h.p. per minute, and this efficiency was obtained only in a few isolated cuts and with a very sharp cutter. Cuts made with a 14-in. face cutter with inserted teeth and on a "No. 4 Cincinnati" high power miller showed a production of 0·64 cub. in. per net h.p. per minute, an increase of 33⅓ per

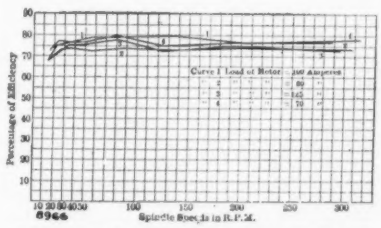

FIG. 11.—EFFICIENCY CURVES OF NO. 4 CINCINNATI HIGH POWER MILLERS.

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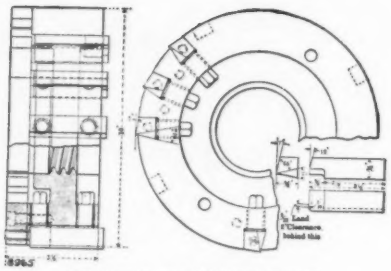

FIG. 12.—10 INCH 16-BLADE CUTTER.

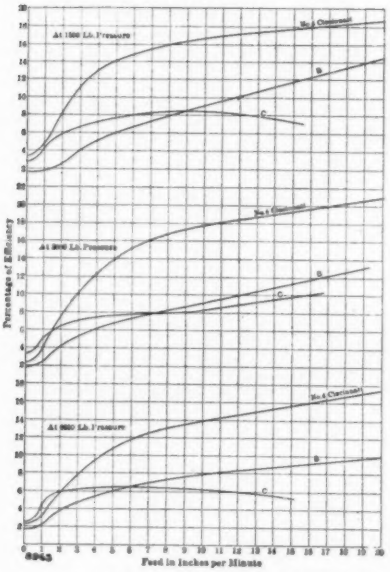

FIG. 14.—FEED EFFICIENCY CURVES AT DIFFERENT PRESSURES.

cent. over the spiral cutter. This result confirms the general belief that a face cutter cuts freer than a spiral cutter. The teeth of this face cutter were radial, as it is customary to make them. Tests made with the cutter shown in Fig. 11 showed an efficiency of 0·96 cub. in. of metal per net h.p. per minute, and a few isolated cuts even higher. This is an improvement of 100 per cent. over the spiral cutter and 50 per cent. over the face cutter with radial teeth. The cutter shown in Fig. 12 showed the same efficiency. Both cutters have the blade set tangent to a circle concentric with the cutter, thus giving them a rake angle of 15 deg. The clearance was 7 deg. The points of the cutting blades were rounded to prevent

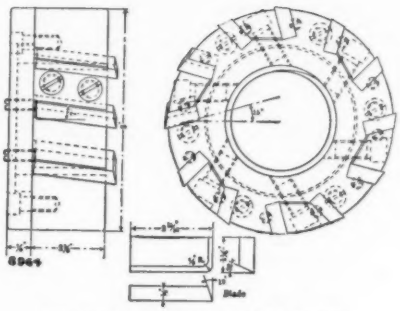

FIG. 13.—8 INCH INSERTED TOOTH CUTTER.

injury by burning or chipping, and this reduced the effective rake near the horizontal tangent to this curve. It was for this reason that the blades were set leaning backward as in Fig. 12. But for this curvature at the point of the blades the simpler construction of Fig. 11 would be perfectly satisfactory. The leaning back of the blades is rather a refinement than a necessary improvement. It should be borne in mind that the tests made with these cutters were on a vertical machine which had the same driving parts as a horizontal machine of the same size, and besides an additional two shafts and four gears, so that it is safe to say that its mechanical efficiency must be less than that of the No. 4 horizontal machine used with the spiral cutter with nicked teeth. The action of the feed on a machine using this cutter may be somewhat different from that on a machine using spiral cutters. Whether there is such a difference and what it amounts to has not been ascertained by tests, and might be a promising field to explore. The fact that, generally speaking, the face cutter with rake removes double the amount of metal with the same amount of power as compared to the spiral mill is significant, and places the vertical machine in the front rank for slabbing work wherever it is possible to use this type. Equally significant is the fact that a cutter with rake removes 50 per cent. more metal than a cutter without rake. It may be mentioned here that many of these cutters, especially for so-called rotary planers, are being made and have been made for a great many years with the teeth leaning backward as in Fig. 12, but without rake, the makers and users apparently believing that this leaning constitutes rake.

I regret that the requirements of patent laws do not permit me at the present date to describe a spiral cutter and a face cutter built on different principles, which have been tested as to their efficiency. It may be of some interest, however, to know that a great number of cuts have been taken with these cutters showing removal of 1·14 cub. in. per net h.p. per minute, and with entire absence of chattering of machine and spring of the cutter arbor.

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A Cheaply Constructed Machine for Milling Petrol Motor Cam-shafts. —Some time ago we received an order to manufacture a number of motor cam-shafts, as shown in Figs. 1 and 2, for four-cylinder 35 h.p. street omnibuses. To those who have never had any experience in the manufacture of these cam-shafts let it be said that it is a most difficult, and highly skilled job to undertake, and one that can be easily under-estimated.

Having got the cam-shafts turned, we proceeded to mill the cams to the required profile. This we did on a universal milling machine, having one of our very best men on the job, as the greatest care has to be exercised, the sides of the cams not being straight. The induction side is curved as shown, whilst the exhaust side has negative rake to allow the valve to close very quickly. This means that the shapes have all to be got by hand, and each camshaft took six and three-quarter hours each to mill, and quite three hours filing up to shape afterwards. Two serious questions at once presented themselves: we were losing money on the job, and also not giving deliveries to time, so we set about to remedy matters and constructed a simple machine, which possesses some points of originality, and a boy can now turn out one cam-shaft complete in an hour, with practically no filing to be done.

Having an old hand-lathe in the shop which we had given up using, we took the bed *A*, and fast headstock *E*, which was 7 in. centres, and planed the centre tongue off the bottom, and also planed a V-square across each end as shown in Fig. 3. A casting, *C*, was made to clamp on the bed *A*, as shown, and planed it so that *E* could slide across it. Next, the bearings were bored out to 3½ in. diameter and a hollow spindle, *H*, fitted, made out of hydraulic tubing, a worm wheel, *G*, being keyed on it. This is driven by a sleeved worm, shown in detail at Figs. 17 and 18, and is carried by a double bracket, *F*. On the end of the worm sleeve the hand-wheel *b*, shown in Figs. 4 and 5, is keyed; it is removed in Fig. 3 to show the gearing. Through the hole in the worm passes a shaft, *Q*, on which is keyed the hand-knob, *a*, which has a dog-clutch cut on its inner boss face, to engage with a similar clutch on *b*. The back end of *Q* has a sunk key let in, and is driven by the large bevel wheel, *R*, supported in the bracket, *S*. *R* is driven by a small bevel, *T*, on the shaft *X*, carried by the two brackets *U* and *V*. *W* is a two-speed cone pulley, *Y* is a weight, hung on a chain *Z*, to keep the headstock

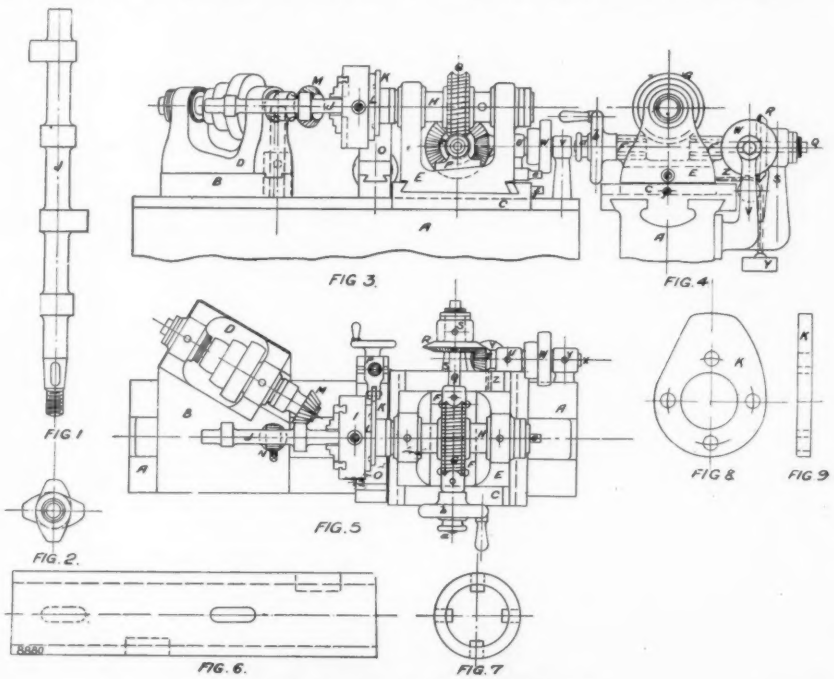
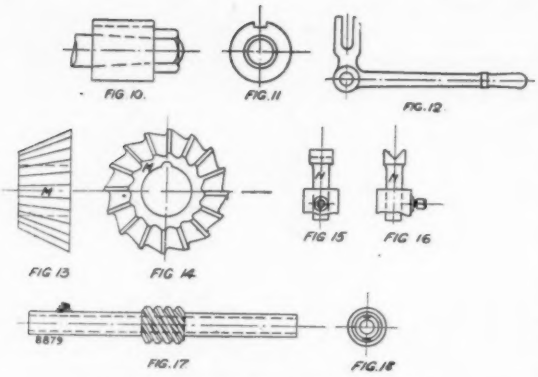


FIG. 1. FIG. 2. FIG. 3. FIG. 4. FIG. 5. FIG. 6. FIG. 7. FIG. 8. FIG. 9.

MACHINE FOR MILLING PETROL MOTOR CAMSHAFTS.



MACHINE FOR MILLING PETROL MOTOR CAMSHAFTS.

E, up against the roller, which is carried on the cut-off rest of a capstan lathe, *O*, in the holder, *P*, and runs against the master cam, *K*, or former. The latter, which is of cast iron, and ¾ in. wide, is shown in Figs. 8 and 9. It is made about four times as large as the cams on the camshaft, to minimise errors. The method of holding the former, *K*, is shown, the adapter plate, *L*, of the chuck, *I*, is turned a good fit to slot in the bore of *K*, which is slotted on and secured by the four bolt holes shown. The cam-shafts, *J*, are gripped in the universal chuck as shown, and are operated on by the bevel cutter, *M*, shown also in Figs. 13 and 14. This cutter is carried on the spindle end of a 6 in. centre capstan lathe headstock, *D*, secured on a planed casting, *B*, which in turn rests on *A*. A slot is planed in the latter into which the central tongue on the bottom of *D* fits, as shown. It will thus be seen that whatever shape the former, *K*, is, an exact replica, on a smaller scale in this case, will be reproduced on the cam-shaft. Should the operator want to get round the cam very quickly or skip a certain part of it, all he has to do is to withdraw the knob, *a*, out of gear with *b*, and then he can turn *b* round quickly. By putting the cranked lever, Fig. 12, on the stud *f*, shown in Figs. 3 and 4, screwed into *C*, and engaging the slotted end with the stud *e*, which is screwed into the headstock, *E*, the work is brought clear from the cutter, as *E* slides in *C*.

The method of locating the cam-shafts in the machine, so that the cams are all cut in relation to each other, a most vital item, is interesting and ingenious. A cast iron bush, with a keyway cut both inside and out, shown at Figs. 10 and 11, is gripped tight on the tapered end of the cam-shaft. This bush is a nice sliding fit in the bored and turned tube, Figs. 6 and 7, the latter having four sunk keys let into it, as shown, exactly in relative positions to the cams to be cut on the shaft, and the same distance apart approximately. This tube is pushed up the inside of the spindle *H*, and secured by a set-screw *d*, in Fig. 3. The cam-shaft and bush are then inserted, and as soon as the keyway in the bush slots on the first key in the tube, the operator knows he is located, and grips the chuck up, and mills the first cam. When completed he releases the chuck, and pushes the cam-shaft along until the bush enters the next key, when he again proceeds. He cannot locate it wrongly, as if the key does not enter the bush is not far enough along the tube, consequently the cam to be milled does not come as far as the cutter. *N* is a support for the outer end of the cam-shaft and is also shown in detail at Figs. 15 and 16. It has a compensating motion, however, to follow the cam-shaft whilst being operated upon, which is not shown.

The machine is quite rigid and does its work in a first-class manner at a mere fraction of the cost of a universal miller, as any boy can operate it when once set. Each cam can be completed easily in fifteen minutes. Most of the parts used are from existing old machines in the shop, only the brackets. *S*, *U*, and *V*, being new, the two castings, *B* and *C*, worm wheel, *G*, worm and bracket for carrying it, together with the two bevel wheels, *S* and *T*, and one or two small sundry items.

The machine paid for itself before we completed the first 100 cam-shafts, and we turned what once looked like resulting in a loss into a handsome profit on the job, since then we have also done several other large batches of cam-shafts in it, to our entire satisfaction. (S. W.)

Grooving Feed Rollers. — Having several feed rollers 5 ft. long and 6 in. diameter, 4-groove each, to turn and groove with ¼-in. spiral grooves, and there being no special machine for this class of work, the writer had to rig up the planer.

Placing the roller in two vee blocks *A A* with a strap across, leaving it free enough to revolve, the next thing was to rig up a motion to turn the roller as the machine travelled. A bracket *B* was picked up with a 1½-in. hole bored through, and standing high enough to allow a spur wheel and pinion to work on the shaft. The wheel *C* and pinion *D* were 3 to 1 gear with the same bore as the bracket, the spur wheel being keyed on a short piece of the 1½-in. shaft *E* and the pinion keyed on the roller shaft. A W.-I. lever *F* with a roller fitted, was fastened on end of the shaft *E* with a set screw so as to allow the grooved roller to be turned to the top for cutting. A 2-in. square bar *G* was next sup-

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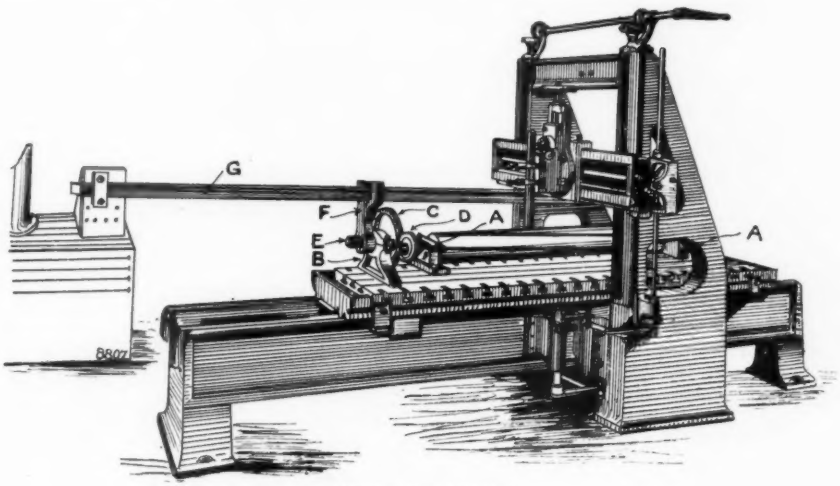
ported under the cross carriage on the planer, parallel to the table, but at an angle with the roller. When the table travelled, the roller in the W.-I. lever rested on the side of the square bar and gave motion to the spur wheel, which turned the roller between the vee blocks. The square bar had to be supported on the far end, having a box bed radial drilling machine near. A strong angle bracket was bolted with a square bar on the front; this was moved back until the right pitch on the roller was obtained. Having marked four teeth off on the pinion wheel, the point of the surface gauge was set to the first tooth, the set screw in lever loosened, and the roller was turned round to the next mark, the cutting being done with a stiff tool holder and ordinary roughing tool, making a quick and first-class job. (J. T. P.)



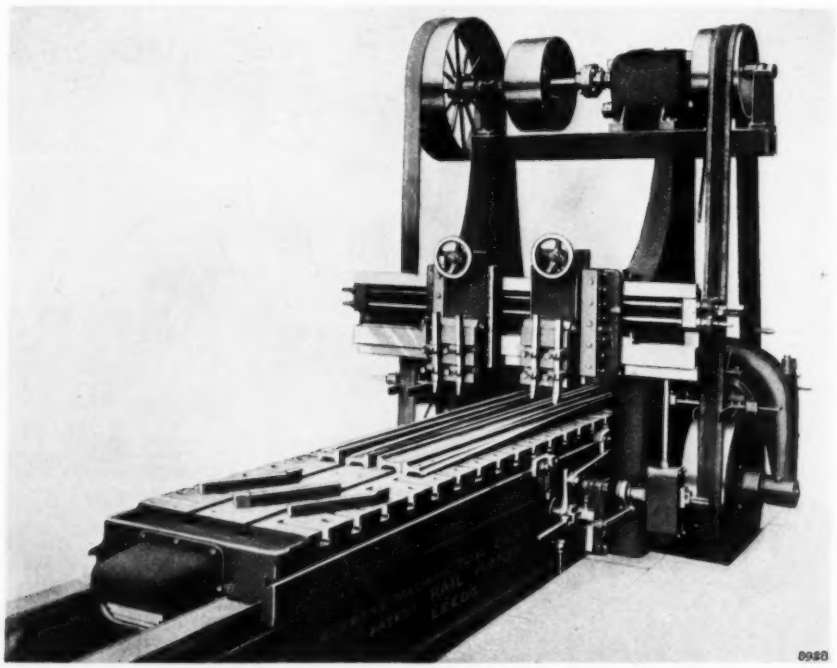
GROOVING FEED ROLLERS.

New Machinery.

The Editor invites advance particulars, drawings, blue prints, photographs, and any data that will enable him to publish an adequate description in these columns of any new work, machinery, or installation possessing special features of interest. In the endeavour to produce a really high-class and technically valuable machinery section the Editor seeks the co-operation of engineers and manufacturers.

A High-Speed Rail Planer.

With the increasing weight and power of locomotives and heavier trains arises the necessity for stronger tracks. Rails of increasing weight and section are consequently demanded by the railway companies for carrying heavier loads. To meet



HIGH-SPEED RAIL PLANER.

Speedometer Readings.		Length of Stroke.	Time of 10 Cycles of Cut and Return.		T.M.C. or Theoretical Mean number of feet Cut per minute.	M.E.C. Mean Effective Cut or number of feet of work actually Cut per minute.	Efficiency.
Cut Speed.	Return Speed.						
Ft. per min.	Ft. per min.		Mins.	Secs.			
38	110	9 ft. 6 in.	3	29	28·1	27·27	·9705
29	110	9 ft. 6 in.	4	23	22·5	21·62	·9631
22½	110	9 ft. 6 in.	5	10	18·95	18·387	·9703

the requirements of manufacturers of rails and crossings for more powerful machines, a machine has recently been introduced capable of planing rails of heaviest section with facility.

The planer is a most massive tool, the design of the machine throughout providing ample cutting power, with great rigidity, so that when taking maximum cuts with the heaviest feed there is no chatter.

Four tools are employed simultaneously. They are held in two massive tool boxes, borne upon a crossrail some 20½ in. deep, and strengthened by an arched back. The support given to the crossrail by the housings is practically solid, for the latter have large, strong bases, and are securely tongued and bolted to the bed, which is itself solid to the ground. In the centre portion of the bed, where the stresses are greatest, it is continued 13 in. below the level of the floor, making a total depth of 36 in. It is of a very strong box section, the sides being stayed by numerous cross-bars, also of box form. The sliding ways for the table are "flats," provided with automatic lubricators. The table is deep and well ribbed, the rack being cut from a solid steel slab.

Any cutting speed between 18 and 60 ft. per minute can be given, and the return speed is 110 ft. On the cut stroke there are 4,042 sq. in. of belt for each foot of table travel, and the makers guarantee a cutting power of 1 in. in depth, 22 feeds per inch, with 4 tools cutting simultaneously in steel of 45 tons tensile strength.

The first machine built was, we are informed, actually tested with four tools cutting 1¼ in. deep, 14½ feeds per inch.

The principal dimensions are as follows: Width between housings, 40 in.; height under crosssail, generally, 12 in.; length of stroke, 10 in. longer than the normal; made any length from 10 ft. long, rising 2 ft. at a time; length overall about 75 per cent. longer than the table or "stroke"; feed range, from 43 per 1 in. to 4¾ per 1 in.; height of countershaft, 8 ft. 6 in.; width overall, 9 ft. 4 in.; width of table, 33 in.; bull or rack wheel, 48 in. diameter, 7 teeth engaging simultaneously with the rack.

The effect of the firm's flywheel drive with which this machine is fitted is shown by the speed tests given in the following table, and taken from a 20-ft. rail planer, fitted with 3-speed gearbox.

Note. — The loss of efficiency includes losses due (*a*) to belt slip between countershaft to driving pulleys; (*b*) to reversals; and (*c*) to accelerations.

The machine, which is manufactured by Bateman's Machine Tool Co., Ltd., Hunslet, marks a step forward in the manufacture of rails.

Acrometer for Indicating Internal Combustion Engines.

With the great majority of internal combustion engines now in use there is absolutely no means of ascertaining what the actual power available is; there is nothing to show to what extent the power is reduced by throttling, nor to show in what degree it is increased by judiciously adjusting the air supply in relation to that of the fuel and in timing the firing properly.

Of course it is well known that by means of an indicator sufficiently delicate the whole cycle may be ascertained, but the diagrams obtained are rather of value in a laboratory, in contra-distinction to an instrument designed for hard and continuous wear, and giving a clear indication on a gauge.

It is with a view to placing in the hands of all interested in internal combustion engines a firm basis whereupon they can rely, which will be a guide as to the power they can call upon, that a new instrument known as the acrometer has recently been introduced by Messrs. Negretti & Zambra, Holborn Viaduct, E.C.

With internal combustion engines, however, the explosion pressure is not the only factor governing the ultimate power of the engine, although to very many a knowledge

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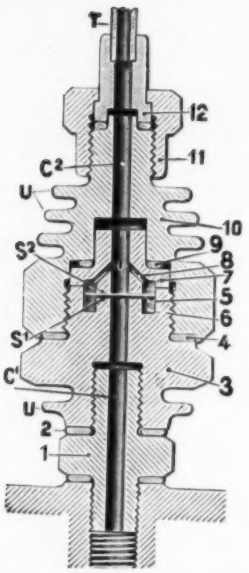


DETAILS OF ACROMETER DISC-VALVE.

of what the maximum pressure is would be a very valuable guide, for the compression pressure, the pressure at the end of the working stroke, as also the suction created at the aspiration of the charge, all have their bearing on the results obtained.

The acrometer is an instrument in which great simplicity has been attained. It gives valuable data from the engines in their ordinary working position and condition, that is, whilst performing their duties *in situ* —on the road, should they be on a motor car.

The essential novelty in the acrometer is the disc-valve, a similar model of this being used in all the patterns, varying according to the pressures it has to deal with.

The accompanying illustration represents the full size of the disc-valve, which in the pressure pattern is mounted on the explosion chamber of the engine. 1 is an extremely hard steel alloy nipple, which screws into the cylinder; 3 is the lower half of the valve body; 8 the valve cap; 10 the upper half of the valve body; *S* 1 and *S* 2 are the valve seatings; and 5 is the valve itself, made of a thin disc of platinum alloy, near to the edge of which is a ring of openings through which the gas may pass; 2, 4, and 9 are copper and asbestos compensation rings; *U* are cooling flanges; *T* is annealed copper tubing leading to the gauge.

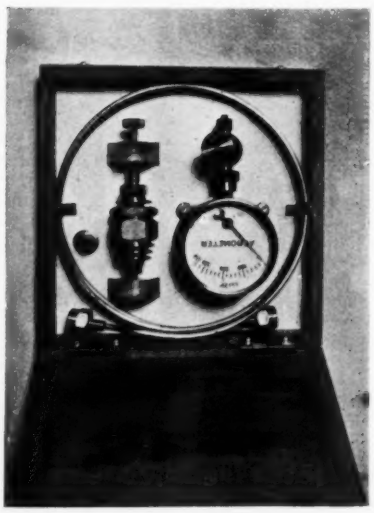
The gauge itself is of a specially made pattern, having an unusually strong, solid drawn phosphor bronze tube, enabling the whole of the scale shown on the dial to be used, and it embodies a special fitting which takes up any lag the pointer might tend to develop. The dial is of silvered and engraved metal.

In the case of pressure being shown by the acrometer, the action is as follows:

At each explosion a small quantity of gas passes to the gauge side of the disc, till in a few moments the gauge hand is steady, which will evidently then show the maximum explosion pressure.

Now if the explosions are subsequently of greater intensity, fresh quantities of gas will be forced to the upper side of the disc, and the gauge pointer will show the higher maximum explosion pressure.

In the event, on the other hand, of the explosion pressure becoming less powerful, no fresh quantities of gas are injected into the gauge side of the valve, and as the volume of gas contained by the piping and the gauge is very small, and it is continually losing its heat and consequently decreasing in volume and pressure, there is a continual tendency for the gauge pointer to come



A 1 PATTERN ACROMETER IN CASE COMPLETE.

back to the zero of the scale. This drop will continue till the lower maximum explosion pressure in the cylinder is reached. It is, of course, obvious that the gauge hand will not fall below this, as the moment the pressure on the gauge side of the valve is less than that of the explosion further quantities of gas are introduced, once again bringing up the gauge pointer. In addition to this automatic drop of the gauge pressure, the fall may be hastened by making use of the release valve with which all patterns are fitted.

To ascertain the compression pressure, all that is necessary is to open and close again the pressure release, the ignition being cut off, and in a moment or two the gauge hand will be steady at the exact compression pressure.

The most simple pattern of acrometer consists of one disc-valve and one gauge with its pressure release valve, together with the connecting piping, as shown in Fig. 2. When a multi-cylinder engine is being dealt with it is necessary to have one disc-valve mounted on each cylinder, but there need only be one gauge used, as the various leads of piping are taken to a valve-box where any one cylinder can be connected through to the gauge; this valve-box also combines a pressure release. Patterns for 2-, 3-, 4-, and 6-cylinder engines are made, and this series has the gauge graduated from 0 to 350 lbs. per sq. in. For use with more powerful engines or with stationary engines there is the B series with gauge to 450 lbs., or 600 lbs. per sq. in.

The pressure at the end of the working stroke is ascertained from the exhaust, a single disc-valve pattern acrometer being used. This disc-valve is mounted on the exhaust pipe as close as possible to the exhaust valves, a small lug or bent pipe being arranged to project into the exhaust pipe to facilitate the gas entering the disc-valve. Taking into account that the exhaust starts before the end of the working stroke, and that the gas continues to expand, it will be found that the pressure shown by the gauge connected to the disc-valve approximates very closely indeed to the pressure in the cylinders at the end of the effective stroke of the piston. The gauge communicating to the disc-valve can be placed close to the pressure and compression indicating gauge.

The suction vacuum is ascertained from a slightly different pattern of acrometer, which can either be mounted on the explosion chamber, or else on the suction pipe, the latter course being perhaps the more general. The gauge used in connection with this acrometer is graduated from 15 lbs. per sq. in. of vacuum to 15 lbs. per sq. in. of pressure, the zero point occupying the centre of the scale. The gauge acting in unison with this disc-valve can be conveniently placed beside the pressure and exhaust gauges, enabling one thus to have all the information shown at a glance in the clearest possible manner.

The vacuum in the suction pipe will express the resistance to the passage of atmospheric air which the openings of the carburettor offer. It will also have to be borne in mind that the vacuum in the cylinders will be slightly in excess of that obtained in the suction pipe, allowance having to be made for any opposition the gas may encounter in passing through the suction valves.

Many applications of this useful series of instruments will undoubtedly appeal to all interested in the advancement of internal combustion engines of all kinds, for the acrometers can be made to give information on many points under the most varied conditions. For example, the effect of using different fuels, or of their use in varying proportions of mixture; the effect of the strength of the aspiration; the influence of air regulation, of the addition of auxiliary fuels; the result of varying the compression pressure; the divergence of the explosion energy resulting from the adjustment of the firing moment; the gradation of the pressure exerted on the piston by the combustion of the charge. Data on all these points can be easily ascertained by the use of the instrument, clearly and simply, and doubtless still further applications will suggest themselves to those interested.

A New Nut-Lock.

The accompanying illustrations refer to an automatic nut-lock that has been recently placed on the market by Messrs. H. J. Miller & Co., 54, Gordon Street, Glasgow. While it bears some resemblance to other devices of the kind in the manner in which the apparatus locks itself to the bolt, the method adopted for holding the nut is different in that this latter is held by the upturned spring ends of the lock itself. A glance at the illustrations will suffice to render these points clear. It would appear to work best with a square nut, but if a hexagon nut be used it should be of sufficient size to enable the corners to engage the side springs of the lock. The lock is simply placed on the bolt and the nut screwed up. The thread of the bolt, it is

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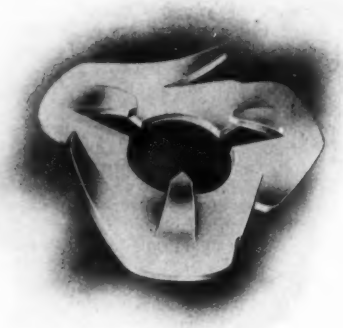

FIG. 1.—NEW AUTOMATIC NUT-LOCK.

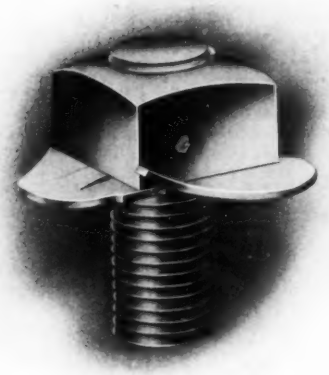

FIG. 2.—SHOWING THE "CLARK" AUTOMATIC NUT-LOCK LOCKING THE NUT.

claimed, is not injured; moreover, the particular part on which the action of the lock depends is not under compression, hence a long life is assured. The nut can be tightened up to take up wear or shrinkage, and it may be removed by turning the nut backwards, when it breaks and falls off. Samples inspected by us show the device to be of solid construction and to render it

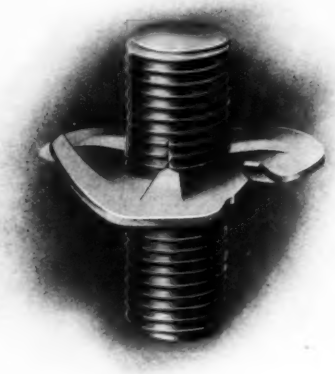

FIG. 3.—SHOWING THE "CLARK" AUTOMATIC NUT-LOCK LOCKED TO THE BOLT.

particularly suitable for railway work, truss rods, agricultural implements, motor cars, &c. It is made in all standard sizes from ¼-inch.

The "Eclipse" Boiler Furnace.

An interesting demonstration was given on the premises of the London County Council, on the 18th inst., before an interested group of engineers, medical officers of health, and gentlemen representative of many branches of enterprise, of a new smoke-consuming device about to be exploited under the name of the "Eclipse" boiler furnace. Briefly, the apparatus consists of a separate gas producer in which steam is passed over incandescent coke, the gas so generated being injected by means of a steam jet into the far end of the boiler furnace behind the fire, where a second combustion is set up. Any unburnt gases or smoke from the boiler furnace are therefore brought into contact with the hot flame of the burning producer gas, and combustion is completed with the consequent suppression of smoke. The boiler with which the demonstration was given was of the ordinary Lancashire type fired with bituminous slack, and a dense volume of smoke naturally resulted with such fuel.

The injection of the producer gas, however, altered the state of affairs and vindicated in a striking manner the claim made on behalf of the apparatus of its ability to secure a practically smokeless chimney. As to the economy of this method of firing but little information was available. It appears that a report on the apparatus has been recently made by Mr. J. Swinburne, the only available figures from which, however, were given as to the cost of raising 1,000 lbs. of steam. Without the producer two tests made with Nixon's navigation coal, at 26*s.* per ton, gave 15·0*d.*, and 15·1*d.* respectively; with the apparatus in use, and firing with bituminous slack, at 14*s.* per ton, three tests gave 9·85*d.*, 10·6*d.*, and 8·75*d.* respectively; or an average of 9·7*d.* On this basis there should be a future for the apparatus in cases where boilers are already installed and the load is a steady one; but in the case of an entirely new installation it would appear that more economical results could be secured by utilising the producer gas in an internal combustion engine.

A New Type of Electric Motor.

There were on view at the stand of the Mitcham Electric Fan Company at the Manchester Electrical Exhibition a number of fans working with a type of motor constructed upon a system which has already given rise to considerable controversy in the electrical world. We refer to the system of field winding devised by Mr. Howard Lacy, whose patents the Mitcham Fan Company are now working. Since the close of the exhibition an opportunity has been afforded us of inspecting the process of manufacture of these motors and of witnessing their method of working, and however much the theory of the revolutionary method of field winding may bristle with difficulties, sufficient evidence was afforded of the undoubted advantages possessed by it with regard to speed and control, rendering motors constructed on this principle of paramount value in cases where a variable speed is required without a considerable proportion of the energy being wasted in resistances as at present.

The understanding of the principle of field winding will be assisted by reference to the accompanying illustrations. The core is made of wrought iron wires instead of solid iron, and has a soft iron disc shrunk upon its ends to bind the bundle of parallel wires together; and to keep the windings in position on the core, plates of some diamagnetic metal are also provided.

In winding the helix, the core is first carefully and thoroughly insulated; then the spools of the magnet are wound in layers, each layer of winding being carefully and effectively insulated. The size of winding wire furthermore is varied in thickness, the layers adjacent to the core consisting of heavier wire than those superimposed thereon. The component wire forming each successive set of layers from the core to the circumference is of diminished thickness, and the thickness of wire of each set of layers is graduated so as to bring in sufficient resistance at each change of grade of wire without producing any excessive retardation of current, the outermost layers being necessarily of the finest grade.

The gradations of thickness of wires are varied and adjusted to circumstances, the windings always increasing in number of layers as they decrease in diameter of component wire.

The wires of the windings are reversed in the direction of their winding at the end of every second layer, the direction of winding of two layers being arranged, say, in the direction known as clockwise and the next two layers in the opposite or contra-clockwise direction, and so on alternately.

Each section of wire is made a distinct coil, and the wires commencing and ending each section are brought out from the core (Fig. 2), and thus can be connected in series or in parallel with the other coils.

As a practical illustration of the manner of manufacture of a coil, take a magnet wound with these coils.

The coil nearest to the core is of the largest sectional area, say, No. 14 S.W.G., and after one thickness of this wire has been wound round the core from end to end, the layer is insulated, and a second winding is applied in the same direction as the first, and the end of the wire is brought out from the core. The spool is again insulated, and two layers of No. 16 gauge wire are then wound on, and the wire is then bent back on itself and fastened (see Figs. 1 and 2) and two more windings are continued but in the opposite direction to those previously wound, there being insulation between every layer. This constitutes a radical difference as compared with all other methods of winding magnets previously adopted, as the effect of the two last turns on theoretical grounds should be to neutralise the effect of the two preceding layers. After again insulating the windings, the same procedure is adopted with No. 18

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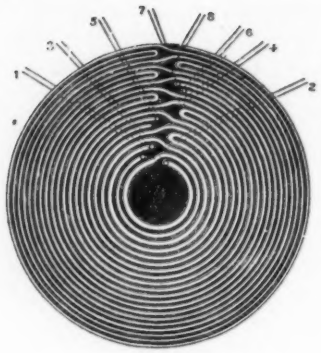


FIG. 1.

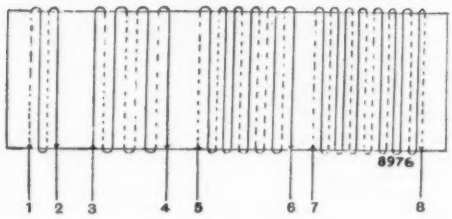
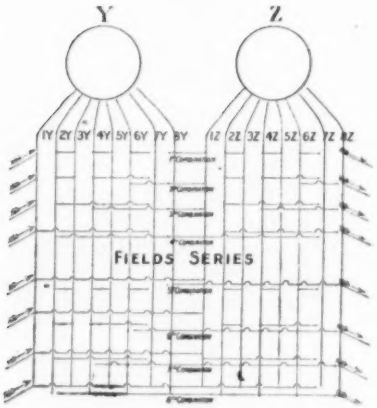


FIG. 2.



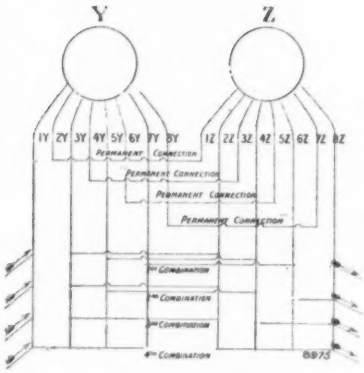


FIG. 3.

DIAGRAM OF NO. 1 METHOD OF CONNECTING LACY MAGNET.

Fields Series.

1st Combination	...	...	All Wires Series.
2nd ,,	...	...	Two Wires Series. / Two Wires Multiple.
3rd ,,	...	...	One Wire Series. / Three Wires Multiple.
4th ,,	...	...	All Wires Multiple.

Fields Parallel.

5th ,,	...	...	All Wires Series.
6th ,,	...	...	Two Wires Series. / Two Wires Multiple.
7th ,,	...	...	One Wire Series. / Three Wires Multiple.
8th ,,	...	...	All Wires Multiple.

DIAGRAM OF NO. 2 METHOD OF CONNECTING LACY MAGNET.

Fields Series.

1st Combination	...	...	All Wires Series.
2nd ,,	...	...	Two Wires Series. / Two Wires Multiple.
3rd ,,	...	...	One Wire Series. / Three Wires Multiple.
4th ,,	...	...	All Wires Multiple.

gauge wire, but the number of turns used is twice as great as in the case of the No. 16 gauge, and so on. Should further windings be added the sectional area of the conductors is decreased, while the number of turns is increased.

The beginnings and endings of each winding being brought, together with the leads, to the controller, many combinations are possible, as shown in Fig. 3. Take a magnet wound with four coils as shown in Figs. 1 & 2; then calling *A* the coil next the iron core, *B* the second, *C* the third, and *D*

the fourth, or outer coil; we may identify them as follows:—

A beginning in 1 and the end 2.
B „ „ 3 „ „ „ 4.
C „ „ 5 „ „ „ 6.
D „ „ 7 „ „ „ 8.

These coils may be connected up in series, and (1) connected to the positive main, and (8) to the negative. (1) May now be connected to the brush of the armature, the positive main to the other brush of the armature, and (8) to the negative main. The second field coil is connected up in a similar manner and so on and the motor is then connected up in series. The other combinations in parallel and in series-parallel will be readily followed from the diagram (Fig. 3), and it will be noticed that the total number of combinations possible is a large one.

It is by varying the combinations in which the wires constituting the various layers are connected up that the strength of the magnetic field is varied. When they are all connected in series, the magnetic field is weakest; whilst with all connected in parallel the field is strongest.

These groupings are effected mechanically by means of a controller, step 1 placing the wires on each field coil in series, with relation to each other, and the armature is in series; step 2 on the controller brings two wires in parallel, and step 3 connects all wires in each field coil in multiple.

Three or more speeds are thus obtained according to the combination, and without the aid of any external resistance. Further, the motors may be put on suddenly to full load without danger, and commutator troubles are practically eliminated. These points were undoubtedly demonstrated in the case of a motor-driven fan on the occasion of our visit to the works; no matter how the controller was manipulated, sparking was practically absent at the commutator.

Since no external resistances are required it follows that a considerable economy in current is effected, and this brings up the question of efficiency. On this point we cannot do better than quote from reports made by Messrs. Morgan Williams and Couzens, and also by W. G. Walker, A.M.Inst.C.E., M.I.Mech.E., both of whom have carried out a series of brake tests with motors constructed on this principle. On a 2½ h.-p. motor the fields of which had been re-wound in accordance with the Lacy invention, the following efficiencies were obtained:—

THREE WIRES PARALLEL AND FIELDS IN SERIES.

R.P.M.	1,320 ...	1,240
Volts	92 ...	91
Amperes	39·5 ...	44
B.H.-P.	3·39 ...	4·34
Efficiency, per cent. ...	70·6 ...	81·8

TWO FIELDS IN PARALLEL AND ALL WIRES IN PARALLEL.

R.P.M.	1,265 ...	1,515
Volts	82 ...	85
Amperes	70 ...	61
Watts	5,740 ..	5,190
B.H.-P.	5·46 ...	5·13
Efficiency, per cent. ...	70·9 ...	73·8

ALL FIELDS IN PARALLEL AND ALL WIRES IN SERIES.

R.P.M.	1,116
Volts	86
Amperes	52
Watts	4,472
B.H.-P.	3·67
Efficiency, per cent.	63·2

ALL FIELDS PARALLEL AND ALL WIRES PARALLEL.

R.P.M.	1,435
Volts	74
Amperes	90
Watts	6,660
B.H.-P.	4·37
Efficiency, per cent.	53·5

On a 4·6 h.p. motor with fields wound on the Lacy principle with 14, 16, 18 and 20 S.W.G. wire, the maximum efficiency for each combination worked out as follows:—

Coils.	Fields.	Efficiency.
		per cent.
Two parallel two series	Series	20
Three parallel one series	Series	62
All parallel	Parallel	76
All series	Two parallel ...	20
Two parallel two series	Two parallel ...	69
Three parallel one series	Two parallel ...	78
All parallel	Two parallel ...	86
All series	All parallel ...	36
Two parallel two series	All parallel ...	65
Three parallel	All series	72
All parallel	All parallel ...	77

It may be noted that the figures were obtained with motors of other makes in which the cases and armatures were unchanged, the fields alone having been re-wound.

Another point which we have so far omitted to mention is the saving in copper obtained by winding the fields on the Lacy system. To illustrate this we cannot do better than again quote from Mr. Walker's report: "In order to obtain tests on a motor of which I had knowledge and experience as a manufacturer, I had the fields of one of my motors re-wound on the Lacy principle. The tests obtained therefrom

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were as follows: 24 in. propellor (ventilation fan), motor fields wound with 28, 30, and 32 S.W.G. *A* signifies 28, *B* 30, and *C* 32."

Amps.	Volts.	Revs.	Cub. ft. of Air per Min.	—
1·85	200	640	4,800	All coils parallel
1·35	200	462	3,200	*A* in series *B C* parallel
1·25	200	434	3,000	*A* and *B* series, *C* cut out
·8	200	20	150	*A B C* in series
1	200	200	1,500	*A* and *C* in series
1·15	200	150	1,200	*C* only
·9	200	10	75	*B C* in series, *A* cut out
1·5	200	584	4,000	*A* only

Weight of Copper in Re-wound Fields.

A	6 ozs.
B	5 ozs.
C	6 ozs.
Total	1 lb. and 1 oz.

Weight of ordinary fields, 3 lb. 1 oz.

On this motor the saving in copper in the fields is therefore 66 per cent. The above table shows the amperes consumed, together with the number of revolutions and the cubic feet of air discharged per minute.

"The motor was one of the ordinary series bi-polar machines with slotted drum wound armature, a cast iron case 8 in. in diameter, the diameter of the armature $4\frac{3}{4}$ in., length $2\frac{1}{2}$ in.; the only difference was that the fields were wound on the "Lacy" principle. The normal maximum speed of our ordinary make is about 600 r.p.m. It is absolutely necessary to be able to vary the speed of a ventilating fan to suit the ever-varying atmospheric conditions or the state of the air in the particular building or room. It is usual to allow for a variation in speed of about 50 per cent., *i.e.*, to reduce the speed from 600 r.p.m. to about 300 r.p.m.; this will halve the cubic feet of air discharged, say from 4,400 to 2,200. In practice this has heretofore been done by an external electrical resistance in order to reduce the voltage at the terminals of the motor, the quantity of current being taken from the mains remaining practically unchanged. In connection with the test, the variation in speed was obtained by the use of the combinations only."

The advantages possessed by the new principle of winding would therefore appear to consist in reduction of first cost, due to the saving of copper in the fields, economy of current, and the capability of varying the speed and power of the motor. The applications of such a motor are obvious, but it will suffice to mention machine tools, electric trams and automobiles, and electric fans, to all of which any advantages accruing from improved speed regulation and low current consumption, are of importance.

The Mitcham Fan Company have hitherto restricted the application of their motor to electric fans, of which a number varying in size from 12 in. to 36 in. are now ready for the market. The following figures show the variation in current consumption with the speed of running and air discharged:—

Diameter of Fan.	Speeds.	Revolutions per minute.	Cubic feet Air per minute.	Watts absorbed, approx.
12 inches	Low ...	260	145	30
	Medium ...	900	650	40
	High ...	1,200	860	50
18 inches	Low ...	200	600	60
	Medium ...	700	1,900	100
	High ...	900	2,300	160
24 inches	Low ...	120	950	54
	Medium ...	410	3,000	168
	High ...	760	5,800	340
30 inches	Low ...	150	2,000	120
	Medium ...	440	6,400	400
	High ...	670	9,800	800
36 inches	Low ...	120	4,000	260
	Medium ...	350	8,600	550
	High ...	500	12,500	800

The company are now devoting their attention to motors up to 10 h.-p., which should find a useful application in the directions above mentioned.

THE INDUSTRIAL-ENGINEERING PRESS

In this section is presented every month a list of the more important articles appearing in the Engineering Press and of the leading papers read before the various engineering institutions. Full names, addresses, and published prices of the publications indexed are printed each half-year in the volume index.

Civil Engineering.

Bridge over the River Wear at Sunderland. *Engineering*, *23rd October*, 1908.

Reinforced Concrete Caissons for a Breakwater at Algorna, Wis. *Engineering News*, *15th October*, 1908.

Permanent Underpinning for the Paris Subway of the Paris and Orleans Railway. *Engineering News*, *15th October*, 1908.

Some Reinforced Concrete Bridges in France. *Engineer*, *30th October*, 1908.

A Traveller for Viaduct Erection. *Engineering News*, *8th October*, 1908.

New 16-acre Dock, Southampton, for London and South-Western Railway, *Railway News*, *17th October*, 1908.

Development of a Practical Type of Concrete Spillway Dam. By R. Muller. *Engineering Record*, *24th October*, 1908.

The Use of Concrete in Reconstructing Folkestone Pier. *Engineering Record*, *24th October*, 1908.

The David Neale System of River Improvement and Bank Protection. *Engineering News*, *22nd October*, 1908.

Structural Steelwork (*continued*). By E. G. Beck. *Mechanical World*, *6th November*, 1908.

Roofs, XI. *Railway Engineer*, *November*, 1908.

Waterproofing of Concrete Covered Steel Bridge Floors. *Railway and Engineering Review*, *24th October*, 1908.

The Construction of the Pelham Bridge, New York. *Engineering Record*, *31st October*, 1908.

Method of Lining the Second Bergen Hill Tunnel of the Lackawanna Railroad. *Engineering Record*, *31st October*, 1908.

The Manhattan Bridge Approach Viaduct. *Engineering Record*, *31st October*, 1908.

A Combined Concrete and Steel Girder Bridge, Monroe Street, Brookland, D. C. *Engineering News*, *29th October*, 1908.

Failure of a Reinforced Concrete Pressure Conduit. *Engineering News*, *29th October*, 1908.

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Adamson, Ramsbottom & Co., Ltd., Birkenhead. Illustrated list of selected types of electric and hand cranes manufactured by this firm.

Leyland Motors, Ltd. Leyland, Preston. Handsome illustrated catalogue steam and petrol industrial vehicles, including standard wagons, timber and tipping wagons, water-carts, &c.

Hans Renold, Ltd., Manchester. Booklet entitled "Driving Chains and their Uses." Extremely well printed and illustrated, is rather educational than commercial, and contains a mass of original information on power transmission that should be of interest and value to every one of our readers. Among the subjects dealt with are: types of chains mostly in use; forms of sprocket teeth; the principles of chain gearing; types of sprockets; tools for making them, and appliances necessary for chain making. The selection of chain drives illustrated covers a wide field and is thoroughly representative of the applications of this form of transmission.

Negretti & Zambra, 38, Holborn Viaduct, E.C. Large bound collection of sectional lists dealing with instruments of importance to surveyors, railway engineers, draughtsmen, meteorologists, &c. These sectional lists are being issued pending the revision of the firm's "Encyclopædic Catalogue," for many years a standard work of reference.

AWARDS AT THE FRANCO-BRITISH EXHIBITION.

Messrs. Small & Parkes, Ltd., Harpurhey, Manchester. Gold medal for their "Karmal" packing and "Roko" belting.

Pulsometer Engineering Co., Reading. Gold medal for their desiccating and steam condensing air pump. This pump, it may be mentioned, is the invention of H. A. Fleuss, well known as the inventor of the "Georgk" vacuum pump.

Hans Renold, Ltd., Manchester. Two gold medals for their display of driving chains in the classes of apparatus for power transmission and of machine appliances and accessories.

Davey, Paxman & Co., Ltd., Colchester. Grand Prize for their balanced two-crank 250 b.h.p. gas engine. One of the most important and up-to-date features of this prime mover is that the crank shaft is a two-throw one with the connecting rods acting on two crank-pins placed at 180 deg. apart; by this means the connecting rod, piston and crank of one cylinder perfectly balance the reciprocating parts of the other, and the engine, in addition to being thus balanced, gets one impulse every revolution. The governing of the engine is on the throttle system. The throttle acts on the gas only, so that the compression remains practically constant, whatever the load on the engine. It is claimed that the special form of combustion chamber and ignition allows this to be done without risk of mixed explosions or back-fires into the air-box owing to weak charges. Also there is an arrangement by which a small quantity of rich mixture surrounds the firing-point at every explosion stroke, so that there is always a sufficient flash of flame to ignite even the weakest mixture.

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